BASIC GAS CHLORINATION

WORKSHOP MANUAL

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INTRODUCTION

The Basic Gas Chlorination Workshop Manual has been prepared as a home study and reference text for treatment plant operators. It includes the information needed by an operator to safely operate and maintain a gas chlorination system employing the solution feed gas chlorinator.

The workshop based on this manual is a working course which includes considerable hands-on training using actual equipment. For successful completion of the workshop, the trainee must achieve a passing grade of 70% in written and hands-on testing.

The Training and Certification Section wishes to acknowledge the assistance and contributions of various manufactures, suppliers, and individuals in the preparation of this manual.

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CHLORINATION THEORY

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CHLORINE AND CHLORINATION

OBJECTIVES:

The trainee will be able to

1. Recall the main purpose of chlorination.

2. Explain the disinfection process when chlorine is the agent.

3. Recall other uses of chlorination in water and wastewater treatment operations.

4. Recall the properties of chlorine.

5. Recall the standards set by the Ministry of the Environment Technical Bulletin 65-W-4 Chlorination of Potable Water Supplies.

6. Define
   a) chlorine dosage
   b) chlorine demand
   c) chlorine residual

   and explain their relationship.

7. Calculate
   a) chlorine dosage
   b) chlorine demand
   c) average chlorine dosage per day

GENERAL

Chlorination may be performed at a water or wastewater treatment plant for many purposes but the most important is disinfection of the plant effluent. When effluents are discharged to bodies of water of water distribution systems, treatment for the destruction of bacteria and viruses is required to minimize the health hazards. Such treatment is known as disinfection. The amount of chlorine necessary to obtain a satisfactory reduction of bacteria will vary greatly with the composition of the influent and/or the degree of treatment the plant provides. The selection of the appropriate disinfection procedures is based on the results of bacteriological tests and other evaluations of the total system.

PROPERTIES OF CHLORINE

Chlorine is a greenish-yellow gas with a penetrating and characteristic odour. It is 2½ times heavier than air, and one volume of liquid chlorine equals 460 volumes of chlorine gas. It can be compressed into a liquid which has a clear, amber colour. At -35°C it has zero vapour pressure. However, as the temperature rises so does the vapour pressure and at 20°C it is 82 psi gauge pressure. This characteristic has to be considered when

1. feeding chlorine gas from a cylinder,
2. dealing with a leaking cylinder.

Chlorine has a high coefficient of expansion. For example, a temperature rise of 25°C (from -5°C to 20°C) will increase the volume by approximately 85 per cent. Such an expansion could easily rupture a cylinder or line if it is full of liquid chlorine. This is the reason for the regulation that all chlorine containers must not be filled to more than 85% of their volume.

Chlorine by itself is non-flammable and non-explosive, but it will support combustion.

TABLE 1-1

PROPERTIES OF CHLORINE
Greenish-Yellow Colour
Heavier than Air
High Rate of Expansion
Moderately Soluble in Water
Non-Flammable and Non-Explosive
Supports Combustion at High Temperature

Chlorine does not kill bacteria and viruses directly but, when chlorine gas and water are mixed together in the chlorinator, hypochlorous acid a strong oxidizing or disinfecting agent is formed.

Chlorine is a surface-active agent and there is a reasonable chance that bacteria hidden within solid particles will not be killed by chlorine. For this reason, chlorine is added for disinfection purposes at a point after solids removal. In water treatment, turbidity removal is important because bacteria can be concealed within the turbidity particles and be inaccessable to the effects of chlorination.

REACTION OF CHLORINE

Chlorine is an extremely active chemical that will react with many compounds to produce many different products. Such reactions complicate the disinfection process because the chlorine demand of these materials must be satisfied as well as those associated with the disinfection reactions. The quantity of both organic and inorganic substances in the influent varies from place to place and from time to time, so the amount of chlorine to be added will also vary. Sufficient time (contact time) must be allowed so that there is complete reaction of the chlorine with the chemical and bacterial pollutants as chlorine is added to water or wastewater. The reactions proceed generally as follows:

1. If chlorine is added, it will first react rapidly with reducing compounds such as hydrogen sulphide and ferrous iron. No disinfection results.

2. As more chlorine enters solution, it will react with the organic matter present to form chloro-organic compounds, which will have a slight disinfecting action.

3. Chlorine added in excess of that required by Steps 1 and 2 will react with ammonia and other nitrogenous compounds to produce chloramines.

The chlorine used by these organic and inorganic substances (Steps 1 and 2) is known as the <u>chlorine demand</u>.

The chlorine used by ammonia and the nitrogenous compounds is known as the <u>combined residual</u> (Step 3).

The combined residual (chloramines) has a disinfection capability but is slow acting and requires a long retention time. To reduce retention time required and increase disinfection efficiency, chlorine in excess of that required in Steps 1, 2, and 3 above can be added. This will destroy most of the chloramines (Step 3) depending on the amount added. If chlorine is in excess of that required to destroy the chloramines, it forms hypochlorous acid or hypochlorite ions. This is known as <u>free residual</u> chlorine.

Total Residual Chlorine is combined residual plus free residual.

Chlorine dosage is chlorine demand plus total residual chlorine.

<u>Combined vs. Free Residual</u>

Whether combined or free residual chlorination is practiced depends on a number of considerations.

1. In water treatment:

   a) Combined residual chlorine is the method of choice when

      i) long contact time is afforded

      ii) high and enduring residuals are desirable

      iii) control of algae, aftergrowths and red water in the distribution system is necessary

      iv) chlorine taste and odour must be prevented or minimized.

   b) Free residual chlorine is the method of choice when

      i) water quality is poor

      ii) short contact time exist

      iii) there are high concentrations of iron manganese and colour

      iv) difficult tastes and odours must be minimized.

2. In wastewater treatment, combined residual chlorination is normally the method of choice because the excessively high chlorine dosage required to provide a free residual is uneconomical.

In Summary:

The amount and type of chlorine residual used is controlled by:

1. degree of chemical and bacterial pollution,

2. contact time in the plant beginning with the application of chlorine until the moment it reaches the first consumer or receiving body of water. for effective disinfection, always add chlorine at a point where complete mixing will occur. A minimum contact time of 15 minutes is recommended.

CHLORINATION OF WATER SUPPLIES

Purpose

While the principal purpose for chlorinating water supplies is disinfection, it serves other purposes:

1. Control of taste and odour problems when free or combined residual chlorination is practised. If too little chlorine is added, the taste and odour problems may become severe.

2. Oxidation of manganese, nitrites, and ammonia, or the destruction of phenols and the removal of algae and slime growth.

Ministry of the Environment Chlorination Objectives

In its Bulletin 65W4, (draft revised March 1980), the Ministry of the Environment has set minimum objectives to be used by treatment plants for chlorination of public water supplies. These objectives are set up on the broadest concept to protect the maximum number of consumers at any one time. Occasionally, these minimum objectives will have to be exceeded in water plant operating practice and a higher residual may have to be used. A copy of the draft Bulletin is at Appendix A.

An operator can follow the guidelines in meeting the minimum objectives, but still produce a water contaminated with coliform bacteria. In these cases, public health is in danger. Immediate changes in the chlorination program must be made, such as:

1. increase the chlorine residual,

2. change the type of residual,

3. change the point or points of application,

4. increase the contact time between point of application and the first consumer.

The water utility is an industry and certain quality control measures are required. One of these is the chlorine residual analyser and recorder (See Topic 5). This equipment must be kept in proper operating order. The record of chlorine residual provides the operator with positive proof of the degree of performance.

The chlorine residual must be checked and recorded as frequently as needed to ensure that an adequate residual is always maintained at or above the minimum required for the plant. See Para 3.1.2 of Appendix A for recommended chlorine residuals.

Topics 10 and 11 Chlorine testing Procedures describe in detail the equipment and procedure for carrying out residual tests.

pH and its Effect on Chlorination

The pH of a water is an indication of its acidity or alkalinity. It can be lowered to corrosive levels by the addition of chlorine, alum and other coagulants. In some cases, the pH of the raw water may already be too low. Regardless of the cause of low pH, it should be corrected to prevent corrosion by adding an appropriate alkali before the water goes to the distribution system. All chlorine compounds are most effective in bacteria and virus destruction at low pH. Any pH correction upwards (above 7.5) should be done after the chlorine has done its work.

CHLORINATION OF WASTEWATER

Purposes

There are numerous reasons for chlorination other than disinfection at a sewage treatment plant. Difficulty arises however since most plants, unless they are very large, are not equipped to apply chlorine at different locations. One should be aware of the possible uses since chlorine is effective in correcting certain problem situations.

Mechanical sewage treatment plants are required to have chlorination facilities including a chlorine contact chamber. All plant or unit by-passes should be directed to the contact chamber in order to provide some reduction in coliforms prior to discharge. the chlorine residual in the contact chamber discharge should be maintained at 0.5 mg/l during periods of required chlorination. Year round chlorination is required at all plants, except in cases where there is no existing or potential impairment of water used for public consumption. If a case can be established, exemption from chlorination for the winter months November 15 to May 15th only, may be authorized by the Ministry.

Odour Control

Odours in sewage treatment plants that are due to an anaerobic condition will usually respond to chlorination. In most cases the problem is to find the best point of application for the chlorine. In the case of primary clarifiers where the sewage has become anaerobic during the sedimentation period, the chlorine should be added to the incoming sewage. (Prechlorination). When the odour develops in the sewers due to a low velocity, the chlorine should be added far enough up the sewer so that it has adequate time to control the anaerobic condition before the sewage reaches the treatment facility.

Industrial wastes with high oxygen demand such as those from packing houses, canneries, milk plants, etc., will turn anaerobic very rapidly and if this type of waste is found to be causing odours it should be chlorinated before it enters the sewer.

In controlling odours it is not necessary to chlorinate to a residual. It has been found that a dosage of 40-60 per cent of the chlorine demand will give satisfactory control.

<u>Aid to Sedimentation</u>

Chlorination of raw sewage will improve the rate of settling in primary clarifiers. This is especially true when the sewage in anaerobic as it destroys the gas forming organisms and prevents the sludge from rising.

<u>BOD Removal</u>

Chlorine reduces the BOD of sewage in two ways. Some of the decomposable matter is oxidized by the chlorine, resulting in a permanent BOD removal. Other compounds combine with the chlorine to form chloro compounds, some of which are toxic to bacteria and others are no longer broken down by bacteria. The BOD reduction will vary from 15-35 per cent depending on the condition of the sewage. Generally speaking, the lowest reduction is obtained in fresh sewage and the highest in anaerobic sewage. A BOD reduction of 2 mg/1 for 1 mg/1 of chlorine is obtained up to the point where a chlorine residual is obtained. Beyond this point the rate of oxidation drops off.

<u>Grease Removal</u>

Chlorination can be used ahead of a clarifier as an aid in grease removal. The chlorine will break the grease emulsions allowing the grease to collect in larger particles that are easier to remove by skimming.

Activated Sludge

There are a number of ways that chlorine can be used to advantage in operating an activated sludge plant. In some cases sludge bulking can be controlled by chlorinating the return sludge. This will require about 5 mg/l of chlorine and should be continued until a satisfactory sludge index is obtained. sometimes at the start of this treatment the effluent becomes quite turbid, but this condition should clear within a day.

When waste sludge that is being returned to the primary clarifier tends to float, chlorination of this sludge will give better settling.

When an activated sludge plant is overloaded, there are several points in the plant where chlorine can be added to reduce the load. It can be used ahead of the primary clarifier to reduce BOD and increase the amount of solids settled, or it can be added to the aeration channels to aid in oxidation. When added to the final clarifier, it can be used to control biological activity and prevent flotation of the sludge. The best point at which to add the chlorine can only be determined by experience and caries from plant to plant.

When a plant has become anaerobic from breakdown or overloading, chlorination is the quickest way to return it to an aerobic condition. In this case, the addition of chloride of lime is more effective than chlorine gas, as the pH is always low when a plant is anaerobic, and the lime raises the pH while the chlorine corrects the anaerobic condition. Care should be taken that the pH is not raised to the point where calcium carbonate is precipitated as it tends to form scale on the diffusers and plug them.

Supernatant liquor from digesters may cause a higher oxygen demand on the activated sludge process than can be dealt with by normal chlorination methods. Due to the high chlorine demand of this liquor, dosages as high as 80 mg/l or more may be necessary to give adequate control.

Some success has also been attained in cleaning air diffusers by feeding chlorine gas into the diffuser headers.

Sludge Thickening

In some plants, sludges, both activated or primary, are thickened before they are pumped to the digester or dewatered. Chlorine can be used here to control bacterial action and better settling and concentration is obtained. To do this it is necessary to maintain a residual of 1 ppm of chlorine in the supernatant liquor above the sludge.

Breakdown of Concrete and Mortar

The hydrogen sulphide that develops in anaerobic sewage can cause other problems besides odour. This gas is quite soluble in water and will dissolve in moisture that has condensed on the walls and roof of a sewer. It is then oxidized by the air in the sewer to sulphuric acid and will dissolve the cement from the concrete and mortar and allow them to crumble. Chlorine, of course, is the answer to this problem, as it will oxidize the hydrogen sulphide before it condenses on the surface of the concrete and will also control the organisms that produce the gas.

CHLORINE DOSAGES

Appendices B, C, D are copies of W & T Bulletins listing chlorine dosages for water supplies, swimming pools and the treatment of sewage. Application of these dosage figures should be governed by MOE guidelines at Appendix A.

Dosage Calculations

It is very necessary for a plant operator to know how to calculate the dosages of the various chemicals used in water and wastewater treatment. It is important to be accurate when figuring the dosage as too little chemical may be ineffective and too great a dosage a waste of money. As a result, for process control the exact dose of chemical to be added must be determined for the purpose of efficient operation of equipment and for economic considerations.

When a plant is designed to treat a particular water supply or wastewater influent, preliminary laboratory tests are carried out to determine the chlorine demand. Knowing the specified combined and/or free residual required from Bulletin (Appendix A) the chlorine dosage is calculated. Chlorine Demand + Chlorine Residual = Chlorine Dosage.

The chlorination equipment is then selected to permit 50% greater dosage than the maximum anticipated. On start up, this predetermined feed rate is applied. Subsequent testing for combined/free residual provides the information which indicates whether this feed rate must be adjusted. The operator must be able to calculate feed rates based on daily flow rates and test results once the plant is in operation.

EXAMPLE 1:

In designing a plant, the chlorine demand of an effluent as determined by testing is 15 mg/l. How many kg of chlorine per day will be required to treat a flow of 20,000 cu m per day when a total chlorine residual 0.5 mg/l is required?

Total Dosage = Chlorine Demand + Chlorine Residual
= 15 + 0.5 = 15.5

In this question it is necessary to utilize the following relationships:

$$1 \text{ mg/L} = \frac{1 \text{ mg} \times 1\ 000}{1 \text{ L} \times 1000}$$

$$= \frac{1 \text{ g}}{1 \text{ cu m}}$$

and also

$$= \frac{1 \text{ g} \times 1000}{1 \text{ cu m} \times 1\ 000}$$

$$= \frac{1 \text{ kg}}{1\ 000 \text{ cu m}}$$

$$\boxed{1 \text{ mg/L} = \frac{1 \text{ kg}}{1\ 000 \text{ cu m}}}$$

In other words for a 1 mg/L dosage rate we need to use 1 kg of chlorine for each 1 000 cu metres of water.

In this problem we wish to dose at 15.5 mg/L so we will require 15.5 kg for every 1 000 cubic metres of water flow. The daily flow in this problem is 20 000 cu m so we will require 20 time this 15.5 kg or 310 kg/day of chlorine.

Chlorinator Feed Rate $= \frac{15.5 \text{ kg}}{1\,000 \text{ cu m}} \times \text{flow}$

$= \frac{15.5 \text{ kg}}{1\,000 \text{ cu m}} \times 20 \text{ cu m/day}$

$= 310 \text{ kg/day}$

A simple formula to remember:

chlorinator Feed Rate (kg/d) $= \frac{DR}{1\,000} \times W$

Replace DR with chlorine dosage rate in mg/L

Replace W with No. of cubic metres of water

EXAMPLE 2

At 8:00 a.m. on Tuesday the chlorine cylinder scale indicated 116 kg and the water meter read 446 000 cu m. At 8:00 a.m. on Wednesday the chlorine cylinder scale indicated 84 kg and the water meter read 484 000 cu m. What was the average chlorine dosage in mg/L during this 24 hour period?

Chlorine used during 24 hr. period = 116 - 84 = 32 kg

Water treated during same period:

484 000 - 446 000 = 38 000 cu m

Average chlorine dosage:

$$\frac{32 \text{ kg} \times 1\,000}{38\,000 \text{ cu m}} = 0.84 \text{ mg/L}$$

A simple formula to remember:

$$\boxed{\frac{c}{w} \times 1\ 000 = \text{mg/L}}$$

EXAMPLE 3

A chlorinator is set at 100 kg/day. If the average daily flow through the plant is 28 000 cubic metres/day, what is the daily average dosage in mg/L.

We are told that the chlorinator is set to feed 100 kg of chlorine into 28 000 cu m of water. This is equivalent to $\frac{100}{28}$ kg for ever 1 000 cu m. or

$$\frac{100}{28}\ \text{mg/L} = 3.57\ \text{mg/L.}$$

or in arithmetic terms

$$\text{mg/L} = \frac{100\ \text{kg}}{28\ 000\ \text{cu m}} \times 1\ 000$$

$$= 3.57\ \text{mg/L}$$

EXAMPLE 4

In a water treatment plant with a flow rate of 7 000 cu m/day the required total chlorine residual is 0.5 mg/L. In testing the operator determines that his total chlorine residual is 2.5 mg/L when the dosage rate is 3.1 mg/L. What should be the correct feed rate be?

Measured Total Residual	2.5	mg/L
Required Total Residual	0.5	mg/L
Excess Residual	2	mg/L

Correct dosage rate is therefore

3.1 mg - 2 mg = 1.1 mg

We can now easily convert this to a correct chlorinator feed rate setting with what we know from previous examples. TRY IT!

(Answer 7.7 kg/day)

APPENDIX A

CHLORINATION OF POTABLE WATER SUPPLIES

ONTARIO MINISTRY OF THE ENVIRONMENT

BULLETIN 65-W-4

ONTARIO MINISTRY OF THE ENVIRONMENT APPENDIX "A"

BULLETIN

CHLORINATION OF POTABLE WATER SUPPLIES

1.0 INTRODUCTION

1.1 Purpose of Bulletin

Disinfection, to kill pathogenic organisms, is the most important step in any water treatment process. In Ontario it is usually accomplished by adding chlorine. This chemical has many other uses in water treatment such as coagulation aid, taste and odour control and maintenance of water quality in the distribution system, but its primary purpose is disinfection. This bulletin outlines the requirements to achieve adequate disinfection and the procedures to follow when it is not achieved. The bulletin also outlines a design standard. New installations should meet the criteria as set out in the bulletin and existing facilities should be brought up to these standards.

1.2 When is Disinfection Required?

Continuous and adequate disinfection is required when the supply is obtained from a surface source; when ground water sources are or may become contaminated, as in fractured limestone areas; when the supply is exposed to contamination during treatment or when emergency conditions such as flooding or epidemic, indicate the need. Disinfection equipment should also be available at those plants where continuous disinfection is not required, to allow temporary disinfection if unsatisfactory or poor bacteriological quality of water is reported. The design of all plants should incorporate suitable connections for disinfecting equipment to be added for this purpose.

1.3 **Types of Chlorination**

Chlorine when added to water immediately dissociates into hypochlorous acid and hydrochloric acid. The former compound can further dissociate to hypochlorite ion and hydrogen. Hypochlorous acid predominates when the pH is below 7.5. It is the compound that is the prime disinfecting agent in a free chlorine residual. However, it is very reactive and will quickly combine with certain compounds (eg. ammonia) and slowly with many other compounds, that may be present in water, to produce a combined chlorine residual (monochloramine, dischloramine etc.). When sufficient chlorine is present so that the reactions that form the combined chlorine are completed, the breakpoint has been reached. The addition of more chlorine will then yield a free chlorine residual.

Of the many regimes of chlorination, simple or marginal chlorination is probably the most common. This is also probably the least effective, especially if it is the only treatment applied to surface water. Chlorine is applied to give an initial total chlorine residual of 0.2 - 0.5 mg/L, predominantly as a combined residual that frequently disappears in the distribution system.

Free residual chlorination produces a much superior disinfecting agent. Sufficient chlorine should be added so that the free residual comprises about 60 to 80 percent of the total residual and it should be maintained through all of the water treatment plant and distribution system. Very high free residuals (super-chlorination) would necessitate at least partial dechlorination, before entering the distribution system, with sulphur dioxide, sodium thiosulphate or activate carbon. The addition of ammonia will produce the more stable but less active disinfectant, chloramine.

If only a chloramine residual is desired, it can be achieved by adding ammonia before the chlorine. However a much higher dose and/or much longer contact time is required to achieve the same degree of disinfection as a free chlorine residual.

Pre-chlorination together with post-chlorination, as required is a frequent mode of operation at Ontario water treatment plants. If organic compounds in the raw water tend to cause formation of chlorinated organics (chloroform, etc) it may be advisable and possible to chlorinate just prior to or after filtration when many organic precursors may have been removed. However, the bacteriological integrity of the water must receive first priority when considering any modification to chlorination practices aimed at reducing the formation of chloro-organics.

2.0 Equipment

Chlorination equipment must be readily available at all water treatment plants. This includes all ground water supplies where chlorination is not continuous.

2.1 Capacity

Chlorination equipment shall have a maximum feed capacity at least 50% greater than the highest expected dosage required to provide a free chlorine residual of 1.0 mg/L in the finished water.

2.2 Duplicate Equipment

Chlorine feed equipment (both gas and hypochlorite chlorinators) at waterworks where disinfection is required, shall be installed in duplicate, to provide uninterrupted chlorination in the event of a breakdown. In addition, spare parts consisting of at least the commonly expendable parts such as glassware, rubber fittings, hose clamps and gaskets, should be provided for effecting emergency repairs.

For a multi-well supply system requiring chlorination for disinfection the standby requirements may be met by one portable unit.

2.3 Chlorinators and Controls

Dependable feed equipment, either of the gas feed or positive displacement solution feed type, shall be used for adding chlorine. Automatic proportioning of the chlorine dosage to the rate of flow of water should be provided at all plants, especially where the rate of flow varies without manual adjustment, or operation of valves and/or switches. Where the chlorine demand is not constant, it may also be necessary to either adjust the chlorine dose through a chlorine residual analyzer, or feed a constant chlorine dose and use the chlorine residual analyzer to regulate the feed of a dechlorinating agent.

2.4 Gas Chlorination

2.4.1 Building Design

Gas chlorine equipment - (chlorinators, weigh scales, chlorine cylinders) must be located in an isolated room or rooms. In larger installations the storage and weighing facilities should be in a room separate from the chlorinators. The construction of the facility should be of fire-resistant and corrosion proof material, have concrete floors and be gas tight. All interior surfaces should be coated with a substance impermeable to chlorine gas.

A set of corrosion resistant scales should be available for weighing the chlorine cylinders. Scales for 69 kgm (150 lb.) cylinders should be of the low profile type. Non-low profile scales shall be recessed in the floor. Safety chains shall be used to retain each cylinder, in storage and on weigh scales, in a safe upright position.

Chlorine should not be stored below ground level and the cylinders must be protected from excessive heat, dampness and mechanical damage. One ton cylinders shall be stored on their sides on level racks.

Where rail cars are used, a dead end siding restricted to chlorine tank cars shall be provided. The tracks must be level and protected by a locked derail or a locked closed switch.

Areas containing chlorine or chlorination equipment shall be clearly marked "Danger! Chlorine Storage" or "Danger! Chlorine Feed Equipment" as applicable. The exit doors with "panic" hardware shall be hinged to open outwardly. There shall be two or more exits if the distance to travel to the nearest exit exceeds 15 feet. All exits from the chlorine room and storage area should be to an outside wall. Access between these rooms is permitted if they have a common wall.

The temperature in the chlorine storage and scale room shall not be higher, and preferably slightly lower than that in the chlorinator room. The gas lines between the scales, chlorinators and injectors shall not be located directly on an outside wall or in a location where low temperatures may be encountered.

2.4.2 **Safety Equipment**

Each plant shall have readily available, a self-contained or air-supplied respirator of the pressure demand type. One respirator shall be located in a conspicuous location outside the area of probably contamination.

Protective clothing including gloves, goggles and safety shoes shall be available for persons handling chlorine.

Eye wash fountains shall be located as near as possible but outside the area of probable contamination.

All chlorine rooms must have a chlorine leak detector alarm system.

Container emergency kits to repair leaking valves, fusible plugs or the tanks themselves are available from chlorine suppliers. There are different kits for each size of tank and the proper size should be available at each water plant.

2.5 Hypochlorite Chlorination

It is important that hypochlorite compounds which contain an algicide not be used as a disinfecting agent in potable water systems.

2.5.1 Safety Procedures

Sodium hypochlorite (a liquid) and calcium hypochlorite (a powder) are frequently used to provide chlorination at small municipal water plants and to disinfect mains and reservoirs. Certain safety precautions must be observed in the storage and handling of these compounds.

Calcium Hypochlorite

Certain precautions must be taken when adding granular calcium hypochlorite.

1) Store containers in a clean, cool, dry area away from any combustible material. Spontaneous combustion can result from improper storage. Keep the containers away from moisture, heat and fire. There should be no smoking in this area.

2) Metal drums should be kept upright and should not be dropped, rolled or skidded. Calcium hypochlorite, if dropped, can explode and burn.

3) Empty containers should be thoroughly rinsed with water.

4) When handling calcium hypochlorite it must never have contact with the eyes and it can cause serious burns in the lungs or on damp skin. Face shields with dust masks together with long gloves and other protective clothing must be worn.

5) When measuring calcium hypochlorite a plastic, glass or enamelled device that is clean and dry must be used. It should only be mixed with water.

Sodium Hypochlorite

Sodium hypochlorite is must safer than calcium hypochlorite but does require much more storage space and is more costly to transport long distances.

1) There is no fire hazard from the storage of sodium hypochlorite but corrosion from spillage can be a problem if the facilities are not corrosion resistant and cannot be well flushed with water.

2) When handling the chemical, proper clothing (gloves, eye goggles, etc.) shall be worn.

2.5.2 Chlorination Procedures

Where a powdered product is used, hypochlorite solution shall be prepared in a separate tank to allow clarification by settling before it is directed to the solution storage tank serving the hypochlorinator. If the water used to dissolve the granular hypochlorite has a hardness in excess of 100 ppm, the water should be softened with hexametaphoshate (Calgon) or an ion exchange unit. Periodic purging of the metering system, with muriatic acid, may be necessary to remove calcium deposits. The acid must be flushed from the system before it is put back into use.

The stability of the hypochlorite solution is increased if the concentration is low; the pH is above 10; iron, copper and nickel content is low; and the solution is stored in the dark at low temperature.

2.6 **Chlorine Residual Testing**

It is important that all surface water supplies be equipped with a continuous chlorine residual analyzer and recorder as well as a continuous turbidity analyzer and recorder; this is especially so at larger plants and where water near the intake could become polluted. All surface water plants should at least be equipped with an alarm system that would indicate when the chlorination equipment malfunctions.

Ground water sources, where poor water quality and/or minimum supervision indicates a possible health hazard, should have an automatic chlorine residual analyzer and recorder equipped with a high and low residual alarm or at least an alarm system that would indicate when the chlorination equipment malfunctions.

All installations must be equipped with a permanent standard chlorine residual testing device. It is preferable to use a DPD comparator test kit, an amperometric titrator or equivalent. The amperometric titrator can be used to check the accuracy of a continuous chlorine residual analyzer. The above methods can be used to measure a free chlorine residual in the finished water, the distribution system or in the stand pipe when an emergency or other circumstances require a free residual.

3.0 **Routine Operation**

3.1 **Chlorine Residual**

3.3.1 **General**

Chlorine can be present in water as either a free or a combined residual. The bactericidal effectiveness of both residual forms is markedly reduced by high pH or turdibity, while it is enhanced by a higher temperature or a longer contact time. A free chlorine residual, while a much more effective disinfectant, also readily reacts with ferrous iron, manganese, sulphides and organic material to produce compounds of no value for disinfection.

3.1.2 **Requirements**

For surface water treatment plants achieving low uniform turbidities (1 FTU or less) with a minimum of 2 hours of chlorine contact or for ground water supplies proven free of hazardous bacterial or viral contamination but still requiring chlorination, the minimum total chlorine residual shall be 0.2 mg/L. For all other chlorinated supplied the minimum total chlorine residual shall be 0.5 mg/L. <u>These are minimum acceptable residuals not target or objective residuals.</u> A minimum contact time of 15 minutes (preferably 30 minutes) before the first possible consumer shall be provided at all times. The chlorine residual should be differentiated into its free and combined portions. It is preferable that most of the residual be a free residual. Adequate disinfection may not occur at these minimum levels if the pH is above 7.5 or the turbidity above 1 FTU.

As circumstances demand the minimum requirements for chlorine residual and/or contact time may be increased.

The chlorine residual test must be performed as frequently as needed to ensure that an adequate chlorine residual is maintained at all times. Such considerations as raw water quality and the resultant variation in chlorine demand, and changing flow rates must be taken into account.

The accuracy of an automatic chlorine residual analyzer shall be checked daily. This shall be accomplished using the amperometric titrator. The results of the check shall be inscribed on the recording chart along with the date and operator's initials opposite a mark indicating the time of the check.

A chlorine residual should be maintained in all parts of the distribution system. This will do little to protect the supply in the event of a main break or some other disaster but should control nuisance growths. The residual should be differentiated into its free and combined portions. The pH of the sample should also be recorded so that the major chlorine constituents in the water can be determined.

The amount and type of chlorine residual present when routine bacteriological samples are taken should be recorded, because this allows a more complete evaluation of the condition of the distribution system.

3.1.3 **Determination**

A representative sample of chlorinated water should be tested. From a tap, the water should be kept running for 5 minutes before taking the sample.

The time when the chlorine residual test should be made depends on where the sample was taken. If the sample has just been chlorinated it should be held for 15 minutes to simulate the minimum contact time, in a covered, demand-free container away from light and heat. However, a sample from the distribution system or finished water after a contact chamber should be tested immediately.

Determination of a chlorine residual should be done by one of the methods outlined in the most recent Standard Methods (14th Edition, 1976) which are preferable to the regular orthotolidine test which has been used extensively. At present the most widely accepted methods are the DPD (diethyl-p-phenylene diamine), both titrimetric and colorimetric, and the amperometric titration. For small water treatment plants or field testing a DPD comparator kit is acceptable.

When using the DPD colorimetric (comparator) test a few important procedures must be observed.

1) The glass cell must be thoroughly rinsed after each test, since any trace of the potassium iodide (Tablet #3) will cause the chloramine colour to develop in the next test for free chlorine.

2) To facilitate dissolving the tablets, they can be crushed while still in their tinfoil packets.

3) Disintegrate tablet #1 in a few drops of the sample in the test cell. Fill the test cell to 10 ml and mix rapidly.

4) The free chlorine residual must be read within 30 seconds of adding the sample to the cell.

5) The total chlorine residual is determined by adding table #3 (crushed) to the same sample in the test cell, mixing, waiting 2 minutes for the full colour to develop and then reading the results in the comparator.

3.2 Records

Minimum records shall include:

1) Daily records of the chlorine used and scale readings.

2) Results from all chlorine residual tests, together with the flow rate and chlorine feed rate and the time of testing.

3) The daily water consumption and the chlorine dosage in milligrams per litre.

4) Details on chlorine cylinder changes, orders and chlorine on hand.

5) Monthly and yearly summaries of chlorine consumption and feed rates.

6) For surface supplies, daily air and water temperatures and weather conditions eg. rain, cloud, sunny, snow etc. together with wind direction and strength.

4.0 Emergency Operation

At all facilities supplying municipal drinking water, a procedure to follow in case of emergency (ie. plant malfunction) must be developed. A list of procedures for the operator to follow must be posted in a prominent location in the plant.

This list must include:

1) The order not to pump unchlorinated or inadequately chlorinated water to the distribution system.

2) The name, address and telephone number of:
   a) Senior supervisory personnel,
   b) Medical Officer of Health and an alternate in the regional health unit if the Medical Officer of Health cannot be reached.
   c) The local M.O.E. District Officer and an alternate,
   d) Chlorinator service company (to be called only if chlorinator needs servicing),
   e) Chlorine supplier (to be called when chlorine required or when tanks malfunction).

3) The exact procedure to follow in order to increase the total chlorine residual leaving the plant to a minimum of 1.5 mg/L.

Wherever chlorination is required, the Ministry of Environment and the Medical Officer of Health must be notified immediately if unchlorinated or inadequately chlorinated water (total residual below 0.2 or 0.5 mg/L or level required) is directed to the distribution system. If this has occurred the Ministry of Environment may require the chlorine feed rate to be increased to provide a 1.0 mg/L or higher residual leaving the plant. Extensive flushing may also be required to carry the residual through the distribution system. Depending on the circumstances additional steps may be required.

When the chlorine residual is increased all customers who may be adversely affected must be notified.

5.0 **Adverse Bacteriological Results**

When the results from bacteriological samples collected from the distribution system indicate unsatisfactory water quality on the basis of the Ontario Ministry of Environment Drinking Water Objectives, (presence of fecal coliform bacteria or the numbers of coliform bacteria five or more per 100 ml) the procedures to follow immediately are:

1) Notify the Ministry of the Environment (increased chlorine residuals may be advised),

2) Collect further samples to confirm the results and determine the extent of the contamination. Chlorine residuals should also be recorded.

If these samples still show unsatisfactory water quality, the Medical Officer of Health and the Ministry of the Environment must be notified and the chlorination increased to provide a total chlorine residual of 1.0 mg/L or a free chlorine residual of 0.2 mg/L at the end of the distribution system. Systematic flushing or swabbing may be necessary in order to achieve and maintain a residual at the ends of the distribution system.

A thorough study of the treatment plant and/or distribution system should be undertaken to determine the cause of the adverse bacteriological results. If the conditions warrant it the Ministry of Environment should recommend to the Medical Officer of Health that a boil-water advisory be issued.

When the bacteriological samples indicate poor water quality (coliform bacteria present at levels below five per 100 ml in more than 10% of the monthly samples or other indicator bacteria - see MOE Drinking Water Objectives) the Ministry of the Environment may recommend some of the following procedures:

1) Initiate chlorination on an unchlorinated supply,

2) Increase the chlorine residual requirements in the finished water to 1.5 mg/L or more, and maintain the level until notified by M.O.E.,

3) Establish a total or free chlorine residual to the end of the distribution system,

4) Disinfect the distribution system as for new mains (Sec. 6.2),

5) Undertake a thorough resampling of the distribution system which should continue until the water quality is again acceptable.

6.0 Disinfection of New and Repaired Mains

6.1 Preparation

Chlorine is predominantly a surface active disinfectant that will not penetrate debris rapidly to kill microorganisms. This debris may also react with the chlorine to reduce its disinfecting power. For these reasons, prior to disinfection of new or repaired works, all the debris must be removed. This can be achieved by extensive flushing with potable water, preferably with foam swabs.

6.2 **Disinfection of New Water Mains**

There are three procedures outlined in the AWWA Standard C601-68.

a) **Continuous Feed Method**

After the main has been cleaned, potable water with a chlorine residual of at least 50 mg/L is fed into the main until it is full. This is achieved by having a constant flow rate and injecting a hypochlorite solution into the main with a hypochlorinator or using liquid chlorine through a solution-feed chlorinator and booster pump. The chlorinated water should remain in the pipe for a minimum of 24 hours, during which time all valves and hydrants are operated to ensure their disinfection. At the end of the 24 hour period, the chlorine residual must be no less than 25 mg/L or the procedure must be repeated.

b) **Slug Method**

This method is suitable for large, long mains where continuous feed is impractical. Following cleaning, potable water is fed into the main at a constant rate. Chlorine is added to the water at a constant rate so that the resulting residual is no less than 300 mg/L. The chlorine dosage is continuous for a sufficient period to ensure that the minimum contact time is 3 hours. As the chlorinated water flows past, all valves and hydrants etc. must be operated to ensure their disinfection.

c) **Tablet Method**

This method is best suited to short, small diameter mains (up to 30 cm (12 inches)). Since the preliminary cleaning must be forgone it is absolutely essential that during construction the pipe interior remains clean and dry. The calcium hypochlorite tablets must be placed at the top of the pipe using an approved adhesive. The main is slowly filled (flow less than 0.3 ms/ (1 ft/s)) to prevent washing the tablets to the end of the main.

Sufficient tablets must be used to result in a final chlorine residual in excess of 50 mg/L. The contact time is a minimum of 24 hours after which the residual must be about 25 mg/L. If the water temperature is below 5° the contact time must be increased.

6.3 Disinfecting Repaired Water Mains

When a leak is minor and the water in the main always has a positive pressure, no disinfection is required after the repair is complete. However, with a more serious break the main must be disinfected before being put back into service. AWWA Standard, C601-68 lists two alternatives. If the broken main need not be put back into service immediately the methods outlined for new mains would ensure better disinfection.

a) Swabbing and Flushing

This procedure is the minimum that may be used. The interior of all pipes and fittings must be swabbed with a 5% hypochlorite solution as they are installed. The chlorine solution can be sprayed on with a small pressurized tank. This is followed by flushing, preferably in both directions, until the coloured water is eliminated.

b) Slug Method

Where possible, the following method should be used. The main with the break is isolated and repaired, then flushed and if necessary foam swabbed to remove all debris. Chlorine is then introduced, as in Sec. 6.2 b), except that the residual may be increased to 500 mg/L and the contact time reduced to ½ an hour. After the contact period the main is well flushed and then put back into service.

6.4 **Bacteriological Testing**

After the new or repaired main has been well flushed with potable water, to remove the heavily chlorinated water, bacteriological samples must be taken to test the effectiveness of the disinfection. If the main is very long several samples should be collected along its length. In distribution systems that normally carry a free chlorine residual one sample or a set of samples (in a long main) is sufficient. However in all other distribution systems a second sample or set of samples should be collected after 24 hours. A main is considered adequately disinfected if there are no detectable coliforms in any of the samples.

New mains must not be put into service until the coliform tests are acceptable. The disinfection process must be repeated if they are not.

If possible repaired mains should also be kept out of service until acceptable results are received. This is seldom possible but if fecal contamination of the main is known or suspected it must be done to prevent a public health hazard. If the test sample(s) are positive for coliforms the disinfection should be repeated.

7.0 **Disinfection of New or Repaired Reservoirs**

7.1 **Preparation**

As with water mains, the interior of storage facilities must be cleaned and free of debris before attempting the disinfection process. This is accomplished by washing down the walls and floors with high pressure jet cleaning equipment and/or long handled brushes. All the debris must be rinsed from the tank interior before disinfection.

7.2 **Disinfection Procedures**

Three methods for disinfection are as follows:

a) **First Method**

This is suitable for tanks where gross contamination has occurred. The tank is filled with potable water to which has been added, early in the process, sufficient chlorine to result in a 50 mg/L residual when the tank is full. The tank is left for at least 6 hours, preferably 24 hours, then drained to waste and refilled from the regular supply.

b) **Second Method**

This method can be used in a relatively clean reservoir, such as following routine cleaning or repair. The walls, floor, and stanchions are sprayed with a 200 mg/L chlorine solution. The tank is well flushed, filled with potable water from the distribution system and put into service.

c) **Third Method**

Water containing 50 mg/L chlorine is placed in the tank to such a depth that when the tank is filled the resultant chlorine concentration is no less than 2 mg/L. The water containing the 50 mg/L chlorine is held in the tank for 24 hours before tank is filled. The full tank in turn is allowed to stand for 24 hours after which the tank may be put into service without draining the water used to disinfect it.

7.3 **Bacteriological Testing**

After the new or repaired reservoir has been filled with potable water, bacteriological samples must be taken to ensure adequate disinfection. If a free chlorine residual is usually carried in the system only one set of samples is required but in all other systems a second set of samples should be collected after 24 hours.

The bacteriological samples must show no detectable coliforms before the reservoir is put into service. If coliform bacteria are detected, the disinfection process must be repeated.

8.0 **Discharge of Chlorinated Water**

Chlorinated water, as used in the disinfection of water mains and reservoirs, can be very toxic to aquatic organisms and it should not be disposed of without careful thought to it effect on the receiving water or sewage treatment plant (STP).

Chlorinated water can be discharged to:

1) Sanitary Sewers - This is a safe course to follow especially if the volume is not great and there is a considerable distance from the point of addition to the STP. However if there is a large volume, eg. with a reservoir, it is essential to contact the municipality to ensure that the operation of the STP is not adversely affected by a hydraulic overload or a massive slug of water with a high chlorine residual.

2) Receiving Waters - This can be detrimental to aquatic life and many fish kills have resulted. Water with a free chlorine residual should not be discharged to a stream or lake. If a combined chlorine residual is present, the concentration at the edge of the mixing zone (where allowed) should be below 0.002 mg/L.

3) Storm Sewer - This should be thought of as directly connected with the receiving water and the same restrictions should apply, even though there could be considerable dilution during wet weather.

4) Drainage Ditch - Discharge to an open ditch is a good alternative, especially if the point of addition is a considerable distance from the receiving water and the ditch is unlined and is full of weeds and other organic material. Sunlight and high temperatures would help to dissipate the chlorine quickly.

If the above conditions cannot be met, a slow discharge of the chlorinated water to a sanitary sewer or ditch can be used. This is easier and cheaper than dechlorination. If dechlorination is necessary (ie. with direct discharge to a small stream), there are several chemicals that can be used effectively. Adequate mixing and dosage of the chemical with the chlorinated water must be ensured. The amount of dechlorination chemical required can easily be determined from the following equation.

Excess chlorine residual x Factor = Dechlorination chemical required

This can be worked out in mg/L, lb's or whatever units are appropriate.

There are five chemicals that can be used to dechlorinate the water:

1) Hydrogen Peroxide - (Factor = 0.479) - This is probably the best chemical when discharging to an environmentally sensitive water course. It is cheap and an overdose will only add more oxygen to the stream.

2) Sulphur Dioxide - (Factor = 0.901) - This chemical is cheap but it will slightly lower the pH in the receiving water.

3) Sodium Thiosulphate - (Factor = 2.225) - This will cause some sulphur turbidity but an excess is harmless.

4) Sodium Sulphate - (factor - 1.775) - Excess will lower the dissolved oxygen in the stream.

5) Sodium Pyrosulphate - (Sodium Metabisulphite) - (Factor = 1.338) - Excess will lower the dissolved oxygen in the stream.

CHLORINE DOSAGES FOR THE TREATMENT OF WATER

PURPOSE OF CHLORINATION	DOSAGE IN mg/L	CONTACT TIME IN MINUTES	RECOMMENDED RESIDUAL mg/L
Disinfection: With Combined Residual With Free Residual	1.0 - 5.0 1.0 - 10.0	Requirements determined by local health authorities	
Ammonia (NH-N) Removal	10 x NH - N content	20+	Free 0.1
Taste & Odour Control	10 x NH - N content plus 1-5 ppm	20+	Free 1.0
Hydrogen Sulfide (H_2S) Removal	2.22 x S when free sulphur 8.9 x S when sulphate	Instantaneous	Free or Combined 0.1
Iron (Fe) Removal	0.64 x Fe content	Instantaneous	Combined 0.1
Manganese (Mn) Removal	1.3 x Mn	Variable	Free 0.5
Red Water Prevention	Maintain a free residual in dead ends	Variable	Free 0.1
Colour Reduction	1.0 - 10.0	15	Free or Combined 0.1
Algae Control	1.0 - 10.0	Variable	Free 0.5+
Slime Control	1.0 - 10.0	Residual needed entire system	Free 0.5+
Control of Iron & Sulphur Bacteria	1.0 - 10.0		
Coagulation Aid for Preparation of: Activated Silica	As Recommended by Supplier	NOT APPLICABLE	

CHLORINE DOSAGES FOR THE TREATMENT OF SEWAGE

PURPOSE OF CHLORINATION	DOSAGE IN mg/L	RECOMMENDED RESIDUAL IN mg/L
Disinfection of:		
Fresh Raw Sewage	6-12	
Septic Raw Sewage	12-25	Requirements usually determined by local health authorities or state regulations.
Fresh Settled Sewage	5-10	
Septic Settled Sewage	12-40	
Chemical Precipitation Effluent	3-10	
Trickling Filter Effluent	3-10	
Activated Sludge Effluent	2-8	
Sand Filter Effluent	1-5	
Odour Control:		
Up Sewer	1.5-10	0
At Plant	5-10	0
Activated Sludge Operation:		
Sludge Bulking Control	2.8	0
Sludge Thickening	Variable	1.0
Trickling Filter Operation:		
Odour Control	2-6	0
Filter Pooling	5-40	1.0-2.0
Filter Fly Control	3-10	0.1
B.O.D. Reduction	6-12	0.2-0.5
Imhoff Tank Foaming	3-15	0
Digester Supernatant	20-80	0-trace

APPENDIX "D"

CHLORINE DOSAGES FOR THE TREATMENT OF SWIMMING POOL WATER

The chlorine dosage requirements of swimming pool waters are dependent on the type and magnitude of the chlorine residual required. This is usually governed by regulatory health authorities.

The conditions which affect the chlorine requirements include continuity of recirculation, rate of recirculation, efficiency of filtration, the number and location of the pool inlets for filtered water, the bathing load, the type and shape of the pool, the type of chlorine residual produced, pH, and alkalinity.

The dosage rate can be based either on pool capacity or on the recirculation rate. Both methods of calculation are used very extensively.

The recirculation rate can be obtained by noting the pump capacity or by multiplying the capacity of the pool by 3, where the turnover rate is three times in 24 hours; or by 4, where the turnover rate is four times in 24 hours; or by any other turnover rate that may be in use in any particular instance.

The usual chlorine dosages, unless otherwise directed by local health regulations, are as follows:

TYPE OF POOL	CHLORINE APPLICATION BASED ON RECIRCULATION RATE	
INDOOR	Average Minimum	Average Maximum
	2.0 mg/L	5.0 mg/L
OUTDOOR	3.0 mg/L	10.0 mg/L

SUBJECT:

CHLORINATION EQUIPMENT

TOPIC: 2

GAS CHLORINATION SYSTEM INSTALLATION

OBJECTIVES:

The trainee will be able to

1. Name the basic types of chlorine feeders and recall their uses.

2. Identify the major components of a typical gas chlorination installation and the purpose of each.

3. Describe the correct method(s) for venting gas feed equipment

   a) when one chlorinator is used

   b) when more than one chlorinator is used

   c) when the chlorinators are of different sizes and types.

GAS CHLORINATION INSTALLATION

CHLORINE FEEDERS

The three basic types of chlorine feeders (or chlorinators) and their uses are:

1. **Dry** (direct) **feed** gas chlorinators are used to apply dry chlorine gas to sewage. They are used only where water under pressure is not available. Their use requires care in selecting the point of application.

2. **Solution feed** gas chlorinators are used to mix an auxiliary supply of water with chlorine gas. The mixture or solution is then applied to the water or the sewage to be treated.

3. **Hypochlorinators** are used:

   a) for relatively low flows,

   b) where chlorine gas cannot be fed for safety reasons,

   c) where the chlorine requirement is small.

   Installation costs are lower than for gas chlorinators, but operating costs are higher. Generally, hypochlorinators are diaphragm-type pumps. Attached for information at Appendix A is a short discussion of hypochlorination.

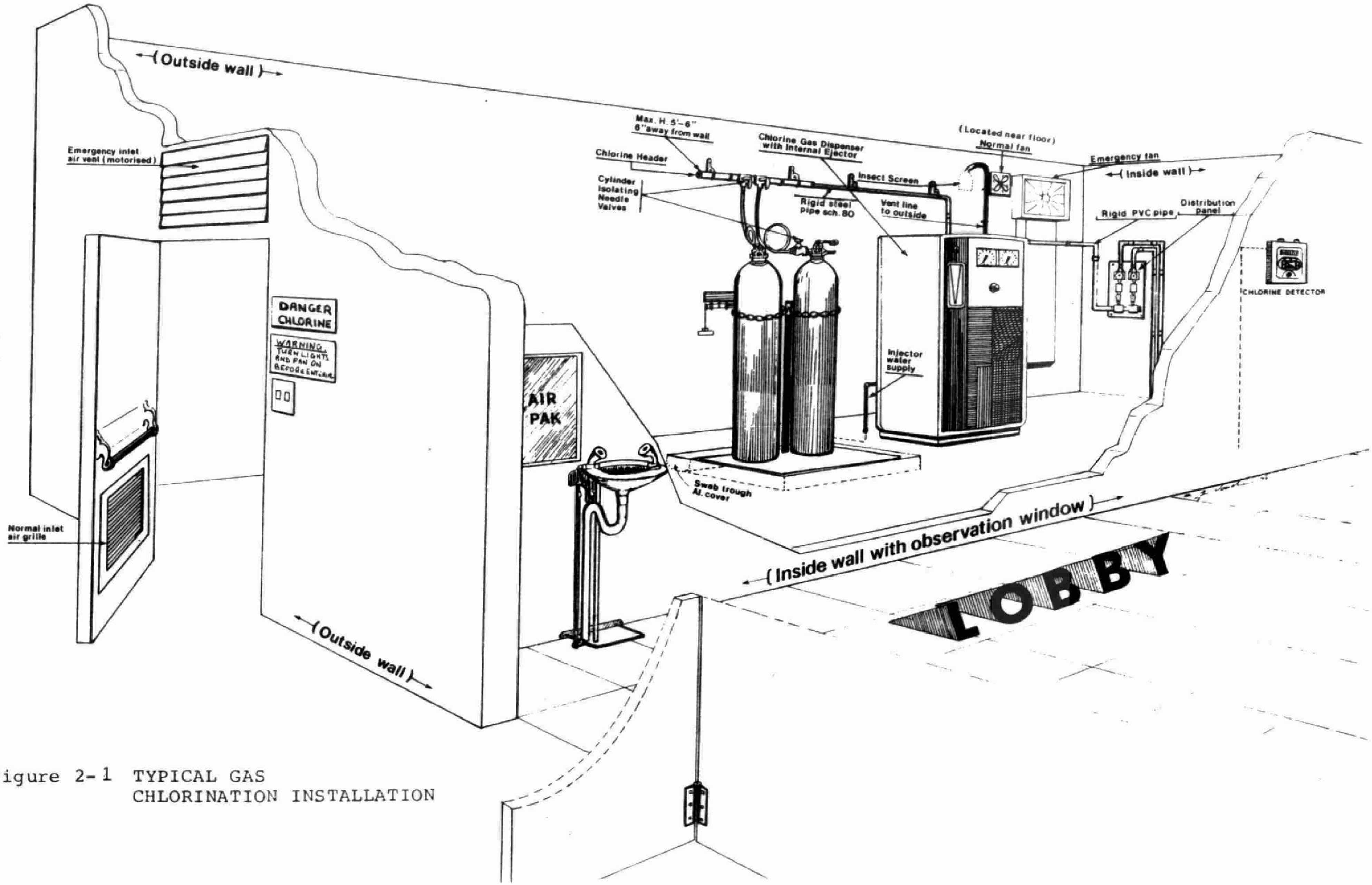


Figure 2-1 TYPICAL GAS CHLORINATION INSTALLATION

Since this workshop manual deals principally with gas chlorination, the following paragraphs describe a typical gas dispenser installation (See Figure 2-1).

Chlorinator

Figure 2-1 depicts a solution feed gas chlorinator, the description and method of operation being dealt with in Topic 4. It should not be installed too close to the wall as the operator must have access to the rear of the chlorinator.

Chlorine Gas Cylinder(s)

Chlorine gas is shipped from the supplier to the water or wastewater treatment plant in 68 kg (150 lb) cylinders, 907 kg (one-ton) containers and in tank cars. The type of container used will depend on the amount ordered and shipped. Topic 3 discusses storage and handling of chlorine.

Chlorine Weighing Scales

The only reliable method of determining the contents of a cylinder is by weighing. The types of scales used in the water and wastewater treatment industry are beam scales, dial scales, and special types of scales.

1. **Beam Scales** are the most common type used in smaller water and sewage treatment plants. Beam scales have a knife-edge type of platform. The weight to be measured is placed on the platform and determined by moving a counter-weight along the beam until the beam is balanced.

2. **Loadcell Scales** have a hydraulic load cell to transmit weight to the dial. Load cell scales are used extensively to measure the amount of chlorine in ton cylinders.

3. **Special Types of Scales** include: electronic, loss of weight recorders, transmitters for remote reading and/or recording, 68 kg or 150 lb container scales.

Flexible Coils (or Pigtails)

Flexible coils are used to connect the cylinder auxiliary valve to the manifold or header valve. They allow movement of the cylinder on the weigh scales, and allow easy connecting and disconnecting of the cylinder.

NOTE:

1. **Do NOT make any sharp bends or kinks in the flexible coils.**
   WHY? (a) to prevent blockage in line
   (b) to prevent possible break in line.

2. **When connecting or disconnecting the coil and the cylinder, always use the two wrenches designed for that purpose.**
   WHY? (a) to hold the flexible coil and prevent twisting
   (b) to prevent breaking of flexible coil off cylinder or header.
   A means of suspending the flexible coil should be employed so as to prevent damage when it is disconnected from the cylinder or header.
3. **Do not connect directly to threads on chlorine cylinder.**
   WHY? so that the treads remain intact for the cap in event of a leaky cylinder valve.

Chlorine Manifold or Header

The chlorine manifold or header is the section of SOLID piping between the chlorinator and cylinder(s) through which the chlorine gas passes from the cylinder(s) to the chlorinator. The flexible coils from individual cylinders are connected to it. Valves should be installed at each flexible connection to permit isolation of a cylinder from the system.

Chlorine Piping Materials

It is most important that the correct material is used for the piping carrying chlorine in its various states, since an incorrect application can result in a potentially dangerous accident.

The three states in which we will commonly find chlorine in the water and wastewater treatment industry are the following:

1. Chlorine gas or liquid under pressure.
2. Chlorine gas under vacuum.
3. Chlorine in water solution.

The material used for piping will depend on which of these states we are dealing with.

1. Chlorine Gas or Liquid Under Pressure

To withstand the effects of chlorine gas or liquid under pressure. Schedule 80 Seamless Steel pipe is used to make up manifold or header piping. Fittings and elbows used must be rated at 2000 # CWP (Cold working pressure) forged steel. Valves and flexible connections must be of a type

approved by the Chlorine Institute. The use of materials other than those recommended will likely result in a leak of chlorine gas under pressure with the associated danger.

Litharge and glycerine or TFE pipe wrap are used for pipe jointing.

Piping must be mounted with a 5 cm gap between the wall and pipe. If gas chlorine piping comes in close contact with any object that would cause a cooling effect (such as a cool wall) the gas may re-liquify.

Pipe must be sloped gently towards gas supply.

Pipe should be labelled.

Piping must not be heat traced or exposed to direct heat source (heater, sun, boiler, etc.).

2. <u>Chlorine Gas Under Vacuum</u>

Where chlorine gas is found in a vacuum atmosphere, the material used for piping is commonly polyvinyl chloride (PVC). Many chlorinator body parts are made of this material or similar plastic products. Where flexible tubing is used in the design of chlorinator body parts, polyethylene or TFE are frequently used.

Care must be taken to prevent liquid chlorine from coming in contact with any of these plastic parts of a chlorination system. This could happen if the supply piping is connected to the bottom valve of a "ton"

container without a working chlorine evaporator on line or where a drop in temperature causes reliquifaction of the chlorine gas supply.

If either of these conditions occurs, damage to the inner surfaces of the plastic parts can be extensive.

Should chlorine gas or liquid under pressure come in contact with these plastic parts, chemical reaction will result in the breakdown of the plastic with resultant leaks of chlorine gas.

3. <u>Chlorine in Water Solution</u>

Piping materials used to carry chlorine solution downstream of the injector may be fabricated from any of the materials recommended for carrying chlorine gas under vacuum or in addition, any material capable of withstanding the effects of strong oxidizing chemicals and low pH, commonly used products are PVC pipe, polyethylene pipe and chlorine resistant rubber hose.

<u>Piping Replacement</u>

Flexible metal tubing connections used to connect chlorine supply cylinders to piping systems <u>shall be replaced annually</u> or sooner if there is evidence of deterioration. Deterioration exists if a pink colour develops on the end fittings (de-zincification due to a tiny leak), if dents or kinks are present (which weaken the tubing), or if the tubing "squeaks" when it is handled (a sure sign of internal stress corrosion).

Pipe, elbows and fittings used to make up chlorine manifolds and supply piping should be replaced every five years or sooner if there is evidence or corrosion. Valves should be removed, refurbished and dried before re-installation.

Booster Pump

Some chlorine installations may not have sufficient water pressure at the injector to form a vacuum. A booster pump may be needed to provide the necessary pressure to overcome friction losses and meet the pressure demands of the system. It should be located in a room separate from the chlorinator and reasonably close to the point of application.

Water Pressure Gauge

A water pressure gauge should be installed close to the injector. It can be used for trouble-shooting injection problems.

Water Pressure Regulator

This unit is used to control and maintain the water pressure at a constant value and eliminate fluctuations caused by the increase or decrease of the pressure. The installation and use of a water pressure regulator can also prevent excessive wear on the injector throat and tailway and cut down on the noise caused by water flowing at very high pressures.

The required water pressure and flow will vary with the amount of chlorine added, and also with the size of the injector.

Strainer Preceding the Injector

It is recommended that a strainer be installed on the water line to the injector. This prevents any possible grit or foreign material from entering and blocking the injector, or causing undue wear on the injector throat and tailway.

If a booster pump is used in the system, the strainer should precede the pump (the injector comes after the pump). A "Y" type strainer is used for ease of cleaning.

The size of screen opening would depend on the size of the injector throat, as well as the foreign materials suspended in the water.

<u>Valves (Excluding Chlorinator Valves)</u>

1. <u>Cylinder Valve</u>

   Used to open or close individual cylinders.

2. <u>Auxiliary Valve</u>

   At the end of flexible coil connecting to the cylinder. If the coil is left disconnected from the cylinder, the auxiliary valve must be closed. This prevents corrosion caused by any moisture accumulation in the coil. (See Figure 2-2)

3. <u>Header or Manifold Valve</u>

   The header valve connects the flexible coil to the fixed piping, or cylinder header. It is used to isolate individual cylinders from the chlorination system. Its construction is similar to the cylinder valve, except that the header valve does not have a fusible plug.

4. <u>Check Valve</u>

   The purpose of the check valve is to stop solution or water from going back into the chlorinator. It is usually installed in the injector suction line.

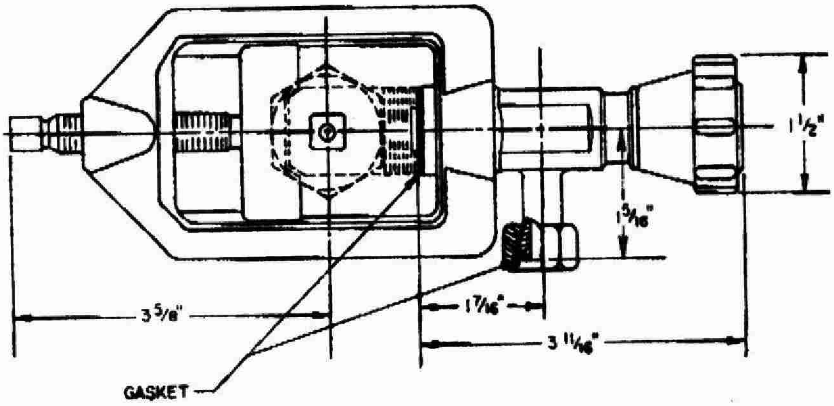


Figure 2-2 CAPTIVE YOKE® AUXILIARY CYLINDER VALVE

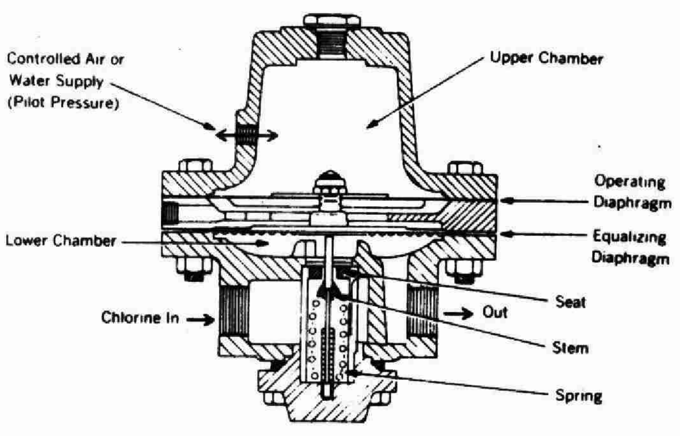


Figure 2-3 Chlorine Pressure Regulating Valve
- Pilot Operated (Air or Water)

5. Relief Valve

Installed in the water line between the booster pump and the chlorinator to prevent any excessive build-up of pressure.

6. Pressure Regulating Valve (PRV) in Header

Used primarily to prevent chlorine gas from changing to liquid chlorine in the line between the cylinders and the chlorinator. The PRV also helps to control the chlorine gas pressure into the chlorinator. It should be located as close to the cylinder as possible.
(See Figure 2-3)

Exhaust Fan

An exhaust fan is installed in the chlorination room to prevent any accumulation of chlorine gas and to provide a specific number of air changes according to the Ministry of Labour Code. It is usually mounted near the floor level on the outside wall of the building. In some cases, the fan is mounted high on the wall or on the roof with an inlet duct going down to within 18 inches of the floor level. The duct vent must be near floor level.

The louvers and blades on the fan should be inspected regularly to ensure trouble-free operation (See Start-Up, Topic 7).

The exhaust fan switch should be located on the outside wall near the door to the chlorine room.

Vent Line

In many water treatment plants, more than one type of gas is used, the most common being chlorine and sulphur dioxide or chlorine and ammonia. Since these gases are not compatible, it is necessary to protect the gas feeding equipment, by eliminating common vent lines. If one machine is drawing from atmosphere and another is discharging to atmosphere at the same time through a common vent line, the discharged gas will be drawn into the other machine. Results would be drastic to internal parts of the equipment and to the interior of the vent line.

Separate vent lines must be used when:

1. more than one type of gas is in use,

2. using one type of gas, but machines of different characteristics, size, or manufacture.

HYPOCHLORINATION

The chemical reactions and analyses are the same as for the solution feed gas chlorinators.

Hypochlorinator is used when gas chlorination is not feasible because:

1. Low flows make initial cost of gas equipment uneconomical
2. Hydro-power not available (see Water Operated Hypochlorinators)
3. Shipping facilities for chlorine cylinders are not feasible
4. Location makes chlorine gas too dangerous for storage and use
5. Where less than 2 kg/day (4 lbs/day) of chlorine (not solution) are required.

FORMS OF HYPOCHLORITE

Powder

The powder is shipped in 23 kg or 46 kg drums (50 or 100 lb) and has up to 65% available chlorine.

Hypochlorite Solution

A saturated solution of chlorine and water (approximately 12%) is shipped in plastic 22 L (5 gal) containers. It can be diluted with water before use.

DANGERS OF HYPOCHLORITE

Powder

1. Protective equipment for skin, eyes and respiratory tract is required to prevent dust from affecting the operator. As this dust has a large percentage of chlorine, moisture in the skin helps to form strong hydrochloric acid, burning and damaging body tissue.

2. Clothing should be protected. Powder (when wetted) becomes a powerful bleach.

3. Contents of drum must be kept dry and covered to prevent powder from hardening, and chlorine fumes from entering the atmosphere.

4. Do not mix different brands in the same container as explosive reactions can occur.

Solution

1. Protection for skin, eyes and clothing is required because of possible spills and splashes.

2. All containers must be kept covered to prevent evaporation and the release of fumes to the atmosphere.

HANDLING

Covered plastic containers are to be used for mixing and storing solutions, as the solution will corrode most metals.

Mixing of powders must be done with as little dusting as possible. Water should be put in the container and powder added - **do not add water to powder.** Initial mixing should be done with container on a stand, so that after the solution has settled for 24 hours, the liquid can be syphoned off into a second container, leaving the residue in the first container for disposal.

Under no circumstances should the suction of the hypochlorinator be allowed to draw any residue from the bottom of the container. This will block up the system.

NOTE: When using sodium or calcium hypochlorite, scale often builds up in the tubing and chemical pump. This is a combination of the chlorine carrier base and minerals from the water in the container being precipitated out by the action of the chlorine. If this causes problems (blocking of solution lines, pump body, etc.), the addition of 1 tablespoon of a water softener (such as Calgon) per 45 L (10 gal) of water before chlorine is introduced, will greatly reduce precipitation.

The strength of the solution can be adjusted to the requirements of the particular installation.

CHLORINE SOLUTION

May be used direct from container.

If the solution is to be diluted, add it to the required amount of water. Again, if the water is very hard, add the softener first if necessary.

NOTE:

1. **All powder or solution should be covered and stored in a cool dry area away from direct sunlight (sunlight and heat will cause breakdown and resultant loss of strength of powder and solution).**

2. **All spills of powder, solution, or mixed solution should be flushed away with copious amounts of water as soon as possible to prevent fumes and damage to other equipment in the room.**

HYPOCHLORINATORS (pumping equipment)

The types of pumps employed as hypochlorinators are:

1. Diaphragm
2. Peristaltic

Diaphragm Pumps

The diaphragm type is the most common in this particular field. It usually consists of a plastic pump head with a plastic or rubber diaphragm and ball or poppet valves. These pumps are usually good for pressures up to 690 kpa (100 psi). These pumps are of a positive displacement type.

Many manufacturers are supplying these pumps in a wide variety of sizes. Motors may be internal or external, solenoid type, depending on the manufacture and the model. Relatively few maintenance problems are involved, provided equipment is kept clean and no leaks of solution are allowed.

Peristaltic Pump

Peristaltic pumps generally consist of a piece of soft resilient plastic tubing around a circular core. Two rollers rotate around the core, driving the liquid ahead of the rollers and into the system. These pumps are not recommended for application against pressures of more than 35 kpa (5 psi), and delivery rates are limited.

Maintenance problems on this type of pump usually involve leaking, collapse of the tube, or improper pressure of the rollers.

PUMP CLEANING PROCEDURES

Periodic cleaning of all these pumps is relatively simple.

1. Shut off pump.

2. Bleed off pressure.

3. Disconnect from point of application.

4. Remove suction line from container.

5. Insert both suction and discharge lines into a 5% muriatic acid solution.

6. Start pump and allow to run until no foam can be seen coming from the discharge.

7. Replace suction tube into container, reconnect discharge line to system and operate.

The point where the solution is introduced to the water system (Point of Application) is especially liable to a build-up of residue. When installing the unit, provide for easy removal to facilitate cleaning.

CONTROL OF ELECTRICALLY OPERATED HYPOCHLORINATORS

These pumps are usually connected electrically with the main pumping systems to stop and start at the same time as the main pump. The stroke length or pump speed on the hypochlorinator is then used to control the residual dosage.

On some of the more sophisticated systems, the speed can be varied on the pump motor to control the hypochlorite flow to meet changing demands. The residual can be controlled by an electric positioner attached to the stroke length adjustment.

Peristaltic pumps do not have a stroke length adjustment and therefore have only one possible control.

WATER OPERATED HYPOCHLORINATORS

Another interesting type of hypochlorinator which receives fairly wide usage is the water operated type. This pump has a plastic solution head with plastic (usually hypalon) diaphragm and poppet valves, but requires no electrical power. It will pump hypochlorite solution in direct proportion to the flow of water through a water meter.

A section is added under the dial unit of the meter which gives a side take-off shaft to control a cam on the hypochlorinator. As this shaft turns, it closes a water valve in the hypochlorinator, and water pressure builds up behind a power diaphragm. This moves the pump shaft ahead and discharges

solution from the hypochlorinator. When the cam releases, the water pressure is discharged from the power diaphragm and a spring returns the pump shaft to its original position, drawing more solution into the pump head.

Since the action of the pump shaft depends on the speed of the water meter shaft, the chlorine addition is in proportion to the flow and the residual is controlled by manually adjusting the stroke length and/or the solution strength.

This system allows treatment in remote, unmanned stations where electric power is not available. It is limited to flow control only.

On all except the peristaltic pump, the discharge will not be constant due to the operating cycle of the pump. Therefore, some attention must be given to proper mixing within the water system before reaching the first consumer.

Some of the modern pumps are now being built with a very short operating cycle, so this problem is not nearly as prevalent as it has been in the past.

ALARM SYSTEMS (CHLORINE DETECTION)

In chlorination, alarm systems are used primarily to warn the operator that chlorine is escaping. Alarm systems can be used to send local or remote signals, or to activate other equipment (for example, scrubbers). The most common sensing cell systems in use to detect chlorine in the atmosphere are amperometric/electrolyte and solid state.

In the amperometric/electrolyte (Figure 2-4), a sample of air is drawn through a sensing cell. Any chlorine present in the air sample will react with the electrolyte to increase the electric signal to an alarm circuit. When the electric signal reaches a pre-set point, the alarm system is activated and remains activated until the chlorine leak is repaired and chlorine is no longer present in the air sample. The electric signal generated by the sensing cell is reduced and the alarm circuit is deactivated.

When equipment failure or malfunction occurs, the alarm system is activated by the vacuum within the chlorinator. If the vacuum **increases** beyond the normal operating level, a diaphragm-operated switch activates the alarm system. Vacuum increase is caused by failure of the chlorine supply.

If the vacuum should **decrease** or drop below the normal operating level, the diaphragm-operated switch will activate the alarm system. Vacuum decrease can be caused by failure of the water supply, plugging of injector, increase in pressure downstream of the injector, or any leak in the vacuum system.

The solid state sensing cell utilizes an electronic device without chemicals. If chlorine is present in the air around the sensor, a drop in electrical resistance of the sensor occurs. This drop in resistance causes an increase in the current from the sensor which then activates the alarm.

Leak detectors should be tested on a weekly basis. Refer to instruction book for test procedures.

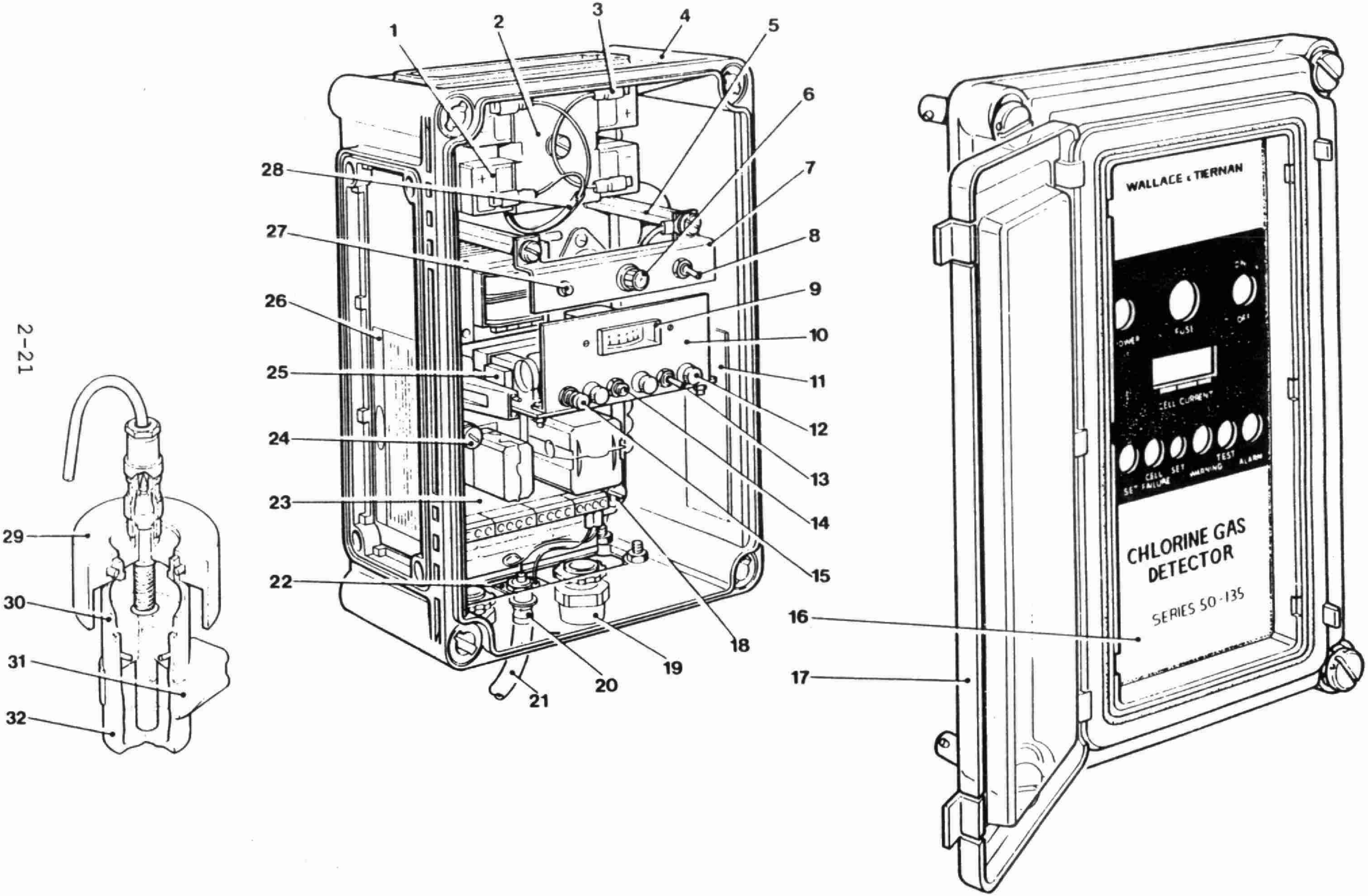


Figure 2-4 ALARM SYSTEM

SUBJECT:

CHLORINATION EQUIPMENT

TOPIC: 3

STORAGE AND HANDLING OF 68 KG AND 907 KG CYLINDERS
CHLORINE EVAPORATORS

OBJECTIVES:

The trainee will be able to:

1. Describe the principle features of *68 kg (150 lb) cylinders and 907 kg (1 Ton) containers.

2. Recall the methods of handling cylinders.

3. Recall the requirements for storage of cylinders.

4. Recall how to determine the weight of the contents of cylinders.

5. Recall the procedures for and demonstrate how to connect/ disconnect cylinders.

6. Recall the purpose of a chlorine evaporator.

7. Describe the safety systems of a chlorine evaporator.

*where "150 lb cylinder" is used in this text, the net weight of contents is 68.0 kg and where "1-ton container" is used the net weight is 907 kg.

CHLORINE GAS CYLINDERS

TYPES

Chlorine is shipped in three types of containers, 68 kg cylinders (the most familiar), 907 kg containers and tank cars. The contents of any of these consist of a liquid phase and a gaseous phase.

68 kg (150 lb) CYLINDERS

Description

CHLORINE CYLINDERS

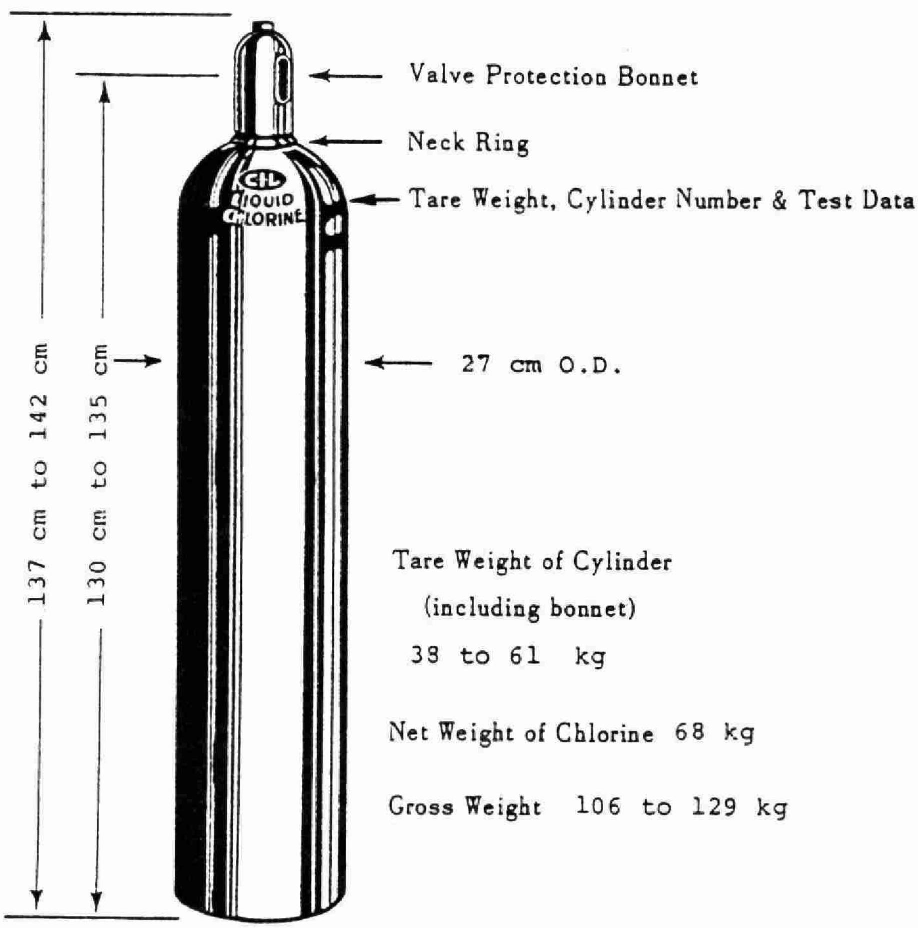


Figure 3-1 **CHLORINE CYLINDERS**

Chlorine cylinders (Figure 3-1) are of seamless steel construction and each is equipped with an approved type of valve. Every cylinder is fitted with a bonnet designed to protect the valve from impact due to knocking or dropping.

Letters and numbers are stamped on each cylinder indicating ownership, specification, cylinder number, tare weight and dates of hydrostatic tests. **It is illegal to deface these markings in any way**.

The 68 kg cylinders are equipped with a single Chlorine Institute standard cylinder valve which has a brass body and a Monel stem. There is a packing gland containing two rings of packing and a fusible plug. Valves are tested and reconditioned or renewed by the manufacturer after each trip. The fusible plug is made of poured metal and located on the side of the valve opposite the outlet. The fusible plug will melt at a temperature of 70°C. This will release chlorine and prevent cylinder rupture due to excessive pressure from fire or cylinder over-heating. (Refer to Figure 3-2)

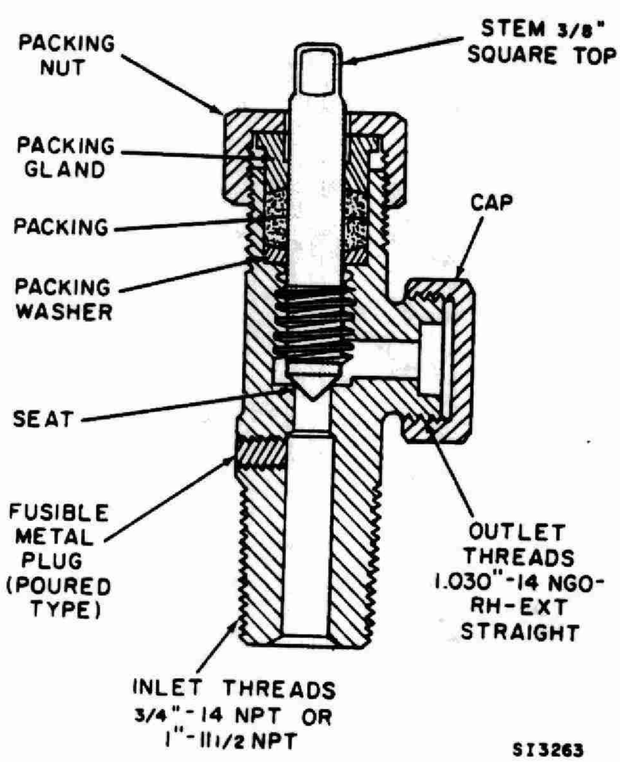


Figure 3-2 Chlorine Institute Standard Cylinder Valve

68 kg cylinders are used in a vertical position for gas withdrawal.

DO NOT RE-USE WASHERS. ALWAYS USE A NEW WASHER.

NEVER LIFT CYLINDER BY THE BONNET.

The protective hood on the 68 kg cylinders is screwed onto a threaded neck ring. Despite its appearance, the neck ring is actually not part of the cylinder, and is often not securely attached to the cylinder.

ALWAYS KEEP THE HOOD IN PLACE EXCEPT WHEN CYLINDER IS IN USE.

Handling - 68 kg Cylinders

When unloading and moving full 68 kg cylinders, do not allow them to be dropped from the truck, and prevent them from falling over or against each other. If the delivery truck does not have a proper unloading device, the plant operator may have to manufacture a safe and acceptable type. Each cylinder should be weighed on receipt. Containers containing in excess of the accepted amount should be returned to the supplier or used immediately. When moving cylinders, use a light three-wheeled hand truck with rubber tires with a clamping arrangement or safety chain at least two-thirds of the way up the cylinder. Whenever possible, two men should be present when moving or changing cylinders. The same care should be used in handling full and empty cylinders.

Experienced operators can safely move a cylinder by rolling it on its bottom edge, but do not let it get out of control and fall, and do not allow the protective bonnet to turn

loose. The protective bonnet should be in position and removed only when the cylinder is being connected to the chlorinating system. Chlorine cylinders should be used only for transporting and storing chlorine.

To lift a cylinder when an elevator is not available, use a crane or hoist with a special cradle. **Chains, rope slings and magnetic devices should never be used for lifting. Never lift a cylinder by the valve-protective bonnet.** The hood is not designed to carry the weight of the cylinder.

Storage

Chlorine cylinders are stored upright and arranged to allow removal of any cylinder with a minimum handling of the other cylinders. Storage space should be well ventilated, easy to get at and kept at normal room temperature. Cylinders should be stored in a dry location because a damp atmosphere will corrode the threads of the protective bonnet, making it difficult to remove.

Empty cylinders should be stored in a separate area from full cylinders. Cylinders must be stored in an upright position and prevented from falling over by using a safety chain anchored to the wall with a snap hook and placed around the outside of each cylinder.

Outside storage areas should be sheltered from the direct rays of the sun, or from excess cold. cylinders should be brought in from the storage area to the chlorine room at least 24 hours before hooking them up to the chlorination system. This allows time for the cylinder temperature to reach room temperature.

CYLINDERS SHOULD **NOT** BE STORED:

1. near combustible or flammable materials such as oil, gasoline and waste

2. on an uneven floor or one covered with debris

3. near the inlet of a ventilating or an air--conditioning unit

4. in sub-surface locations

5. near an elevator shaft

6. near any source of direct heat such as a furnace, heating element or radiator.

7. with any other gases or chemicals

Weighing the Cylinder

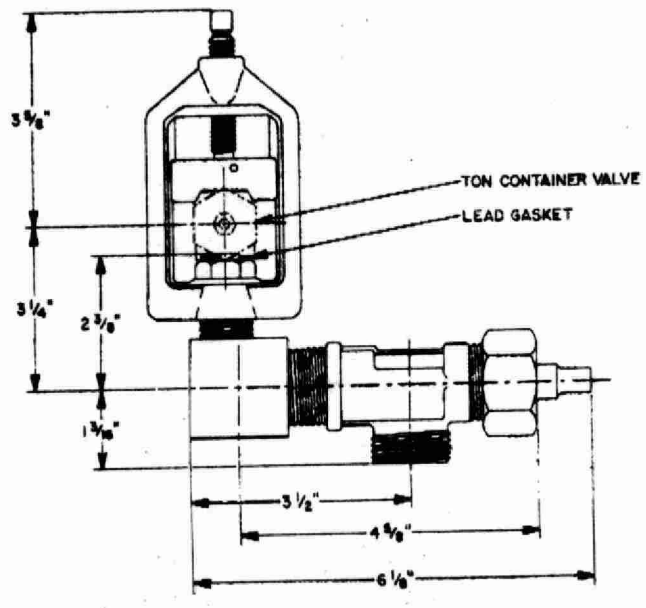
The only reliable method of determining the contents of a cylinder is by weighing. **The pressure in a cylinder depends upon the temperature**, not upon the amount of chlorine in the container. Where convenient, the cylinder should stand on a scale throughout the entire period of discharge. In any event, the only sure method of determiningg whether or not the cylinder is empty is to weigh it and check its weight against the tare stamped on the cylinder shoulder.

Cylinder Connection

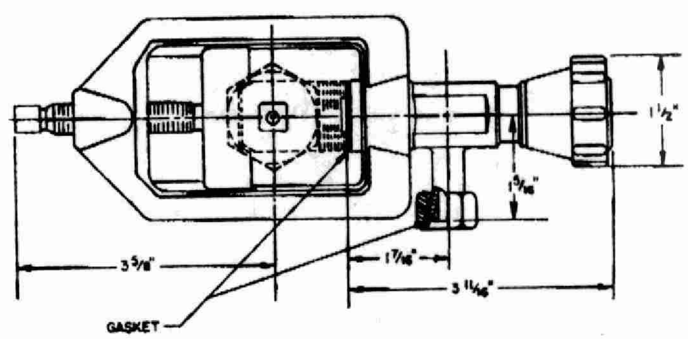
Wear a protective face shield, chemically resistant gloves and long sleeved garment when changing cylinders or piping. A standby person wearing a self-contained breathing apparatus (S.C.B.A.) in readiness shall be present to assist should an emergency occur.

The standard way of making a connection to the valve is with a yoke clamp, adapter a small lead gasket and auxiliary valve. (See Figure 3-3). These three items are supplied by the chlorine suppliers.

When making connections with piping having threaded couplings instead of the yoke type, **two wrenches must be used:** the large spanner for the coupling and the small spanner holding the squared area of the pipe itself at the coupling. Use the flat spanner or box-end wrenches supplied by the manufacturer for all chlorine cylinder pipe connections.



CAPTIVE YOKE TYPE



CAPTIVE YOKE® AUXILIARY CYLINDER VALVE

FIGURE 3-3 Yoke Assemblies for TON cylinder(left),small on right

To connect a cylinder to the chlorinating system using the clamp and adapter, proceed as follows

1. Secure the cylinder to a building column or solid, upright support;

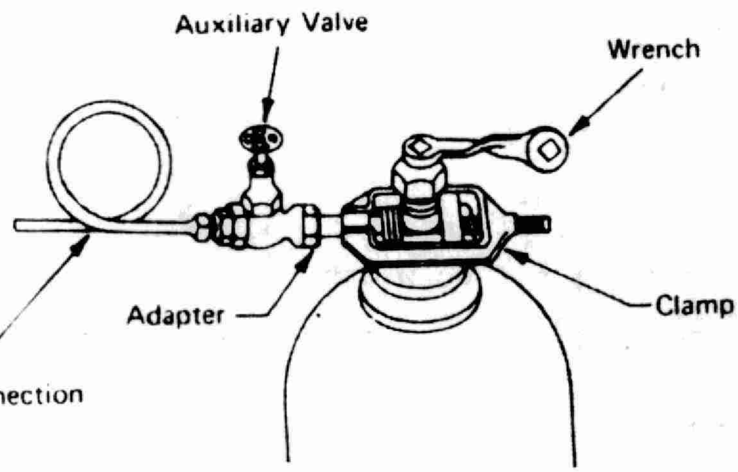
2. Remove the protective bonnet. If the cylinder has been exposed to the weather for a long time, the threads at the base of the bonnet may have been corroded, in which case a few smart raps on opposite sides of the bonnet will loosen it so it can be unscrewed easily;

3. Remove the brass outlet cap and any foreign matter which may be in the valve outlet recess. Use a two-inch nail to clear out any old washer or pieces of lead in outlet recess;

4. Place a new lead of fibre washer in the outlet recess;

5. Inspect the yoke adapter for rounded or worn edges at the contact point of the adapter clamp;

6. Place the clamp over the valve. Insert the adapter in the outlet recess and then, fitting the adapter in the clamp slot, tighten the clamp screw. Make sure the end of the adapter seats firmly against the lead or fibre washer. Figure 3-4 shows a cylinder connected to the coil.



7. The piping from the cylinders to the header located on the wall or to the chlorine machine must have an inverted loop of not less than 25 cm (10") in diameter in its length. The loop acts as a flexible coupling.

Disconnection

To disconnect a cylinder, having followed the shut down procedure in Topic 7.

1. Close the cylinder valve; **Use the wrench provided,** grasping the valve in one hand and tapping the wrench in a clockwise direction with the palm of the other. If the valve does not close tightly on the first trial, it should be opened and closed lightly several times until proper seating is obtained. **Never use a hammer or any other tool to close the cylinder valve tightly.**

2. Detach the flexible coil from the cylinder by loosening and removing the clamp. This coil should be supported while the empty cylinder is being replaced by a full one. For example, support it on another cylinder, use a hook, or a stick from the floor (a broom would be handy). This will prevent the development of weak spots in the pipe.

3. If the pipe line is disconnected for any length of time, plug or cap the open end of the pipe, and shut the auxiliary valve. There is a danger of moisture forming in the line.

4. Screw the protective bonnet in place as soon as the cylinder is disconnected, so that the valve parts will be protected from the moisture in the air. The outlet cap of each valve is fitted with a gasket which is designed to fit against the valve outlet face. If a valve leaks slightly after closing, the leak may be stopped by drawing up the valve cap tightly. If the gasket is not in position, an outlet cap may be taken from another cylinder or a suitable gasket may be cut from an asbestos or synthetic rubber sheet. When the valve cap is used to stop a leak, the gland nut should also be well tightened.

907 kg (1 TON) CONTAINERS

Description

The 907 kg container has two valves, very similar to the one on the 68 kg container; in fact, the only difference is that these valves do not have a fusible plug. Instead, the ton cylinder has three separate fusible plugs in each end, which will melt at 70°C and discharge the chlorine from within. The delivery

rate of chlorine from a ton container will depend on the temperature of the liquid in the container, but an average flow is about 9 kg (20 lb) per hour of chlorine gas. When the 907 kg cylinder is set on the scales, the two discharge valves should be one above the other. The top valve will discharge chlorine gas. The bottom valve will discharge chlorine liquid. (Refer to Figures 3-5 and 3-6). Figure 3-7 shows a typical one-ton cylinder hook-up.

Never operate valves in such a manner as to isolate chlorine gas or liquid in a line. In some installations using one-ton cylinders, there is a short length of tubing running between cylinder(s) and evaporator(s). There is a valve on the cylinder and one on the evaporator line. See Figure 6-1. The tubing between the two is full of liquid chlorine during normal operation. If for some reason the valve on the evaporator line is closed and then the cylinder valve shut, the tubing is left full of liquid chlorine. A small increase in temperature will cause a considerable increase in gas pressure. With the tubing full of chlorine and closed at both ends, there is no room for gas expansion and a potentially dangerous situation exists.

The safe procedure is to close the cylinder valve first and then allow sufficient time for the chlorine in the tubing to be exhausted by the evaporator before closing the evaporator inlet valve. This is the procedure followed when changing cylinders.

Storage and Handling

907 kg cylinders must be moved by an approved lifting bar and hoist, and not by rolling them along the floor.

General storage conditions are the same for both the 907 kg and 68 kg cylinders.

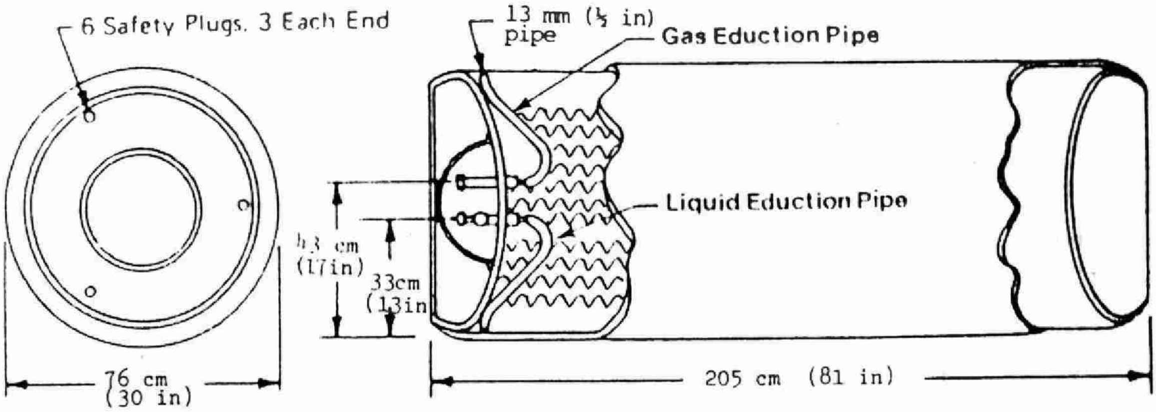


Figure 3-5 CROSS SECTION OF TON CONTAINER

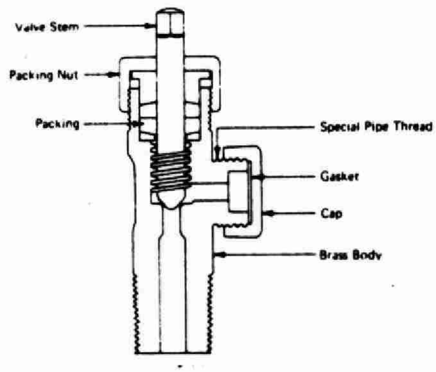


Figure 3-6 TON CONTAINER VALVE

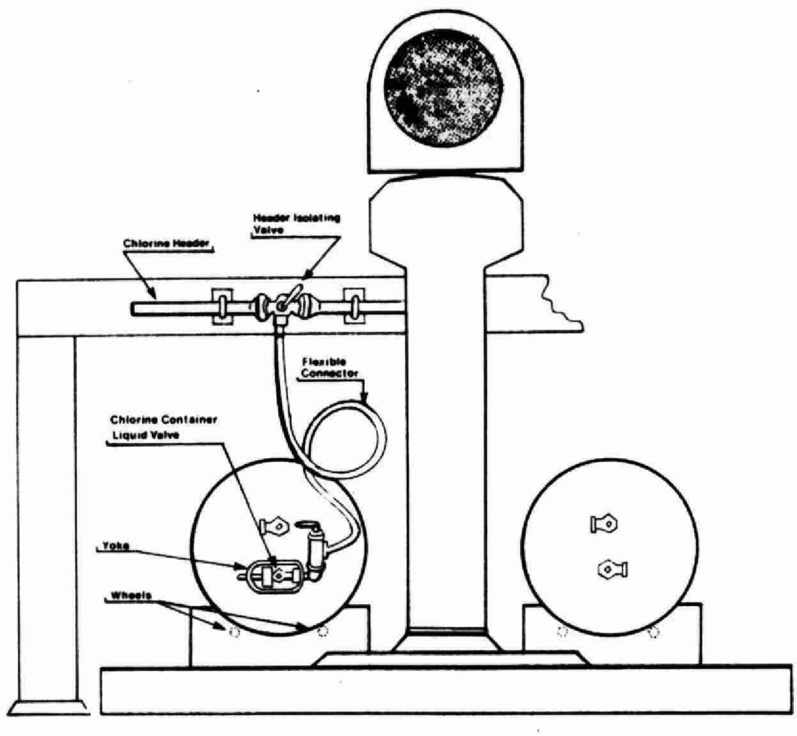


Figure 3-7 TYPICAL ONE-TON CYLINDER HOOK-UP WITH SCALES

Connecting One-Ton Cylinders

The procedure for connecting one-ton cylinders to header or chlorinator is the same as described for the 68 kg cylinders, and should be followed accordingly.

CHLORINE EVAPORATORS

Where volumes of chlorine gas in excess of 450 kg/day are required for extended periods to satisfy chlorine demand, the use of two manifolded "Tonners" is no longer adequate. At usual room temperatures, withdrawal rates exceeding about 200 kg/day of chlorine gas from each "Tonner" result in frosting of the container and cyclical gas pressure changes. The heat transferred through the walls of a container from the air is inadequate to support the evaporation of chlorine liquid to gas for these feed rates.

In order to achieve these rates, some controlled source of heat must be used to safely assist this evaporation process. A "Chlorine Evaporator" is used for this purpose.

WARNING: HEAT MUST NEVER BE APPLIED TO ANY PART OF A GAS CHLORINATION SYSTEM BY ANY MEANS OTHER THAN AN APPROVED CHLORINE EVAPORATOR

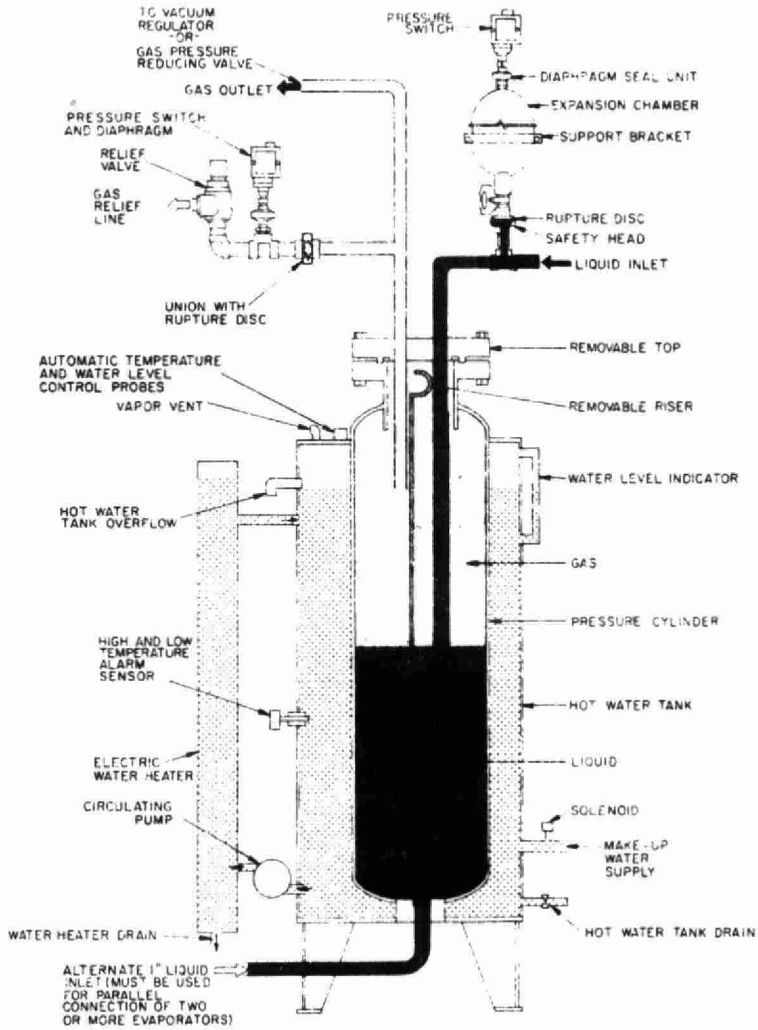


Figure 3-8 Chlorine Evaporator

OPERATION PRINCIPLE

As indicated in Figure 3-8 liquid chlorine from the source container is piped to the evaporator cylinder. This cylinder is immersed in a controlled-temperature hot water bath. The bath supplies the heat to convert the liquid chlorine to gas. Liquid chlorine enters the cylinder to a point near the bottom and the vapour leaves from a point near the top. This arrangement

limits cylinder pressure to that of the source container and prevents the complete filling of the cylinder with liquid chlorine. The heat transfer surface in the gas-filled portion of the cylinder super-heats the chlorine gas.

As the liquid chlorine enters, it contacts the hot inner surface of the evaporator cylinder, it boils and increases the pressure in this cylinder. When sufficient gas has formed to satisfy the demand of the chlorination process, the incoming liquid chlorine flow stops because the pressure in the evaporator cylinder and supply container have equalized. If too much liquid chlorine enters the evaporator cylinder, more gas is formed than required by the chlorination process. The evaporator cylinder pressure rises slightly above that of the supply container causing some liquid chlorine to be forced back into the supply container until the pressure in the evaporator cylinder and supply container have again equalized. Therefore, as long as the line to the supply container is open, the liquid level in the evaporator cylinder is automatically adjusted by the rate of gas used. If no gas is withdrawn, the evaporator will empty itself as the gas formed pushes the liquid back to the supply container.

Conversely, if more gas is called for than a particular liquid level is able to generate, the liquid level will rise causing more liquid to change to gas to meet the demand.

SAFETY SYSTEMS

1. Evaporator Gas Pressure Relief System

Since a dangerous condition will occur if both the inlet and outlet valves of the evaporator are closed at the same time, some means of dealing with the dangerous increase in chlorine gas pressure in the evaporator cylinder and piping must be installed. Usually this is accomplished by the use of a rupture - disc pressure/relief valve system.

The pressure relief is vented to a location outside the building or in some cases to a "scrubber". Once the rupture disc bursts, an alarm device will indicate an over-pressure problem. Care must be taken to avoid a situation where the evaporator is valved off during operation, since pressure relief includes the hazard of venting chlorine gas as well as "down time" while a new rupture disc is installed. To shorten down time following a pressure relief, a replacement rupture disc should always be stocked.

2. <u>Liquid Supply Pressure Relief System</u>

If the liquid supply piping to an evaporator is valved off, trapping liquid chlorine between the valves, a dangerous pressure build-up will occur. To prevent pipe rupture and resultant chlorine release, a liquid line pressure relief system is used. It consists of a rupture disc, alarm and expansion tank. When the pressure builds up, the rupture disc bursts, activating the alarm. The liquid chlorine enters the expansion tank, thus reducing the pressure. As with the evaporator gas pressure relief system, a replacement rupture disc should be kept on hand.

3. <u>Alarm Sensors</u>

Since many of the control devices in a chlorine evaporator are essential to safe operation of the evaporator, sensors are installed to monitor their operation. These sensors are then connected to visible gauges, warning lights, or audible alarms. Examples of common alarm-sensing points are evaporator temperature, gas pressure, water level and pressure relief.

4. <u>Inspection</u>

In many jurisdictions, the operation of a chlorine evaporator falls under a Pressure Vessel Legislation. Provision is made in this legislation to perform an inspection before startup and at certain intervals. Some jurisdictions required the posting of a Pressure Vessel Certificate near the evaporator. Before startup of an evaporator, the operator should be certain that all requirements of applicable legislation have been met.

<u>INITIAL STARTUP</u>

Before any evaporator is started up for the first time, the person in charge of the startup should be certain that he has read the instruction book provided by the evaporator supplier and also that he understands all instructions, notes, cautions and warnings contained therein.

Before chlorine is introduced into the evaporator and its connecting pipe lines, the chlorination should be ready for operation. Operation of the chlorinator may be necessary to dispose of chlorine to permit repair of leaks.

Initial pressure testing should be done with a <u>dry</u> inert gas (instrument air, or nitrogen) at pressure levels recommended by the supplier. For the duration of the initial pressure testing period, the piping to the pressure relief rupture disc should be capped off to prevent rupture by the elevated test pressure.

Once the evaporator system has been proven pressure--tight using inert gas, a final leak test is performed, with the evaporator up to temperature using chlorine <u>gas</u>. From this point onward all pressure relief systems should be on line. connect the supply piping to the gas valve (rather than liquid) on the

chlorine supply container. Using gas rather than liquid for this final leak test permits much quicker disposal of chlorine in the event of a leak. Once the system has been proven leak-free using ammonia test vapours, the system is ready for start up.

STARTUP

Close all valves between the evaporator and the source of supply. Then open the gas valve at the tank car or the ton container and test for leaks using the ammonia supplied with the evaporator. Open valves, progressively testing for leaks as each new section is filled with chlorine. If a leak is discovered, shut off the gas supply immediately, open the other valves in the line and operate the chlorinator to dispose of the gas. Repair the leak before proceeding.

After the system up to the chlorinator inlet valve has been tested and found acceptable, close the gas supply valve and run the chlorinator to exhaust the gas in the evaporator and in the inlet line. When the evaporator pressure gauge reds zero, the evaporator chlorine outlet valve may be closed. If the evaporator pressure gauge shows pressure after the outlet valve has been closed for several minutes, repeat the above procedure until the evaporator pressure gauge holds zero. When this is done, disconnect the piping from the gas valve and connect it to the liquid valve on the supply container. Open the liquid valve slowly and check this new connection for leaks.

WARNING: ONCE THE LIQUID SUPPLY VALVE HAS BEEN OPENED, WHICH SHOULD NOT BE DONE UNLESS THE EVAPORATOR WATER BATH IS UP TO OPERATING TEMPERATURE, THE EVAPORATOR HEATER(S) MUST BE ON AND ALL VALVES IN THE LIQUID SUPPLY LINE LEFT OPEN UNTIL EITHER THE SUPPLY OF LIQUID HAS BEEN

EXHAUSTED OR THE SUPPLY LINE AND EVAPORATOR ARE BEING EMPTIED BY THE CHLORINATOR OR OTHER DISPOSAL. FAILURE TO FOLLOW THE WARNING MAY RESULT IN DISCHARGE OF GAS FROM THE RELIEF SYSTEM.

SHUTDOWN

For cleaning or repairs or long term shutdowns, shut the evaporator chlorine outlet valve for a period of approximately 30 minutes. Under these conditions, most of the liquid chlorine will be forced back to the supply tank through the inlet nipple and remaining liquid will be evaporated by the heat of the water bath. At the end of this period, shut the valve at the tank car of the ton container; immediately open the evaporator chlorine outlet valve; and run the chlorinator to exhaust the gas in the evaporator and the gas and liquid in the inlet line. When the evaporator pressure gauge reads zero, the chlorine outlet valve may be closed. If the evaporator pressure gauge shows pressure after the outlet valve has been closed for several minutes, repeat the above procedure until the evaporator pressure gauge holds zero with outlet valve closed. then turn off power to the control system, alarm units, water heater and water circulator pump. If no standby evaporator is being used, shut down the chlorinator.

WARNING: THIS PROCEDURE OF FORCING CHLORINE LIQUID BACK INTO THE SUPPLY CONTAINER MUST NOT BE USED WHERE THE POSSIBILITY OF OVERFILLING A CONTAINER EXISTS. IF SUFFICIENT CAPACITY IS NOT SAFELY AVAILABLE IN THE CONNECTED CONTAINER(S), ADDITIONAL EMPTY CONTAINERS MAY BE REQUIRED.

CATHODIC PROTECTION

Most evaporators are supplied with some sort of active or passive cathodic protection system. This consists essentially of a set of "sacrificial" anodes of a metal which corrodes in preference to the steel of the evaporator cylinder (cathode). Frequently an ammeter on the cabinet of the evaporator indicates the amount of protective current passing from the anodes to the evaporator cylinder. A variable resistance control, also on the cabinet is used to regulate the current flow and thus ensure economical anode lifespan.

EVAPORATOR CLEANING

With time and usage, impurities from the liquid chlorine will be deposited in the bottom of your evaporator cylinder. By observing the values shown on the evaporator pressure and temperature gauges, an operator will be able to recognize an indication that his evaporator needs cleaning.

The chlorine gas temperature gauge will show a drop in gas temperature, at a given pressure and rate of withdrawal, as impurities are deposited inside the chlorine cylinder. With some experience the operator can use this indication to determine when the evaporator will need cleaning. As long as there are no blockage or closed valves between the evaporator and the supply, the pressure within the evaporator cylinder is the same as the pressure within the tank car or ton container, which in turn is a function of the temperature of the liquid chlorine in the tank car or ton container. By reading the pressure gauge on the evaporator cylinder, a close approximation of the liquid chlorine temperature can be obtained by references to the temperature/pressure scale on the face of this gauge.

After evaporation at this temperature, the chlorine gas will pick up heat during its passage through the evaporator. The additional heat picked up is called "Superheat". The amount of superheat at a particular time is a function of the difference in temperatures between the water bath and the liquid chlorine, the efficiency of heat transfer through the wall of the chlorine cylinder, and the rate of withdrawal of gaseous chlorine. The face of the chlorine pressure gauge is graduated for chlorine pressure and the equilibrium (evaporating) temperature at that pressure. In evaporators equipped with a gas temperature gauge, an approximate value of superheat can be obtained by reading the chlorine pressure and chlorine gas temperature gauges. for example, pressure is 85 psi and temperature gauge reads 87 degrees F. Reference to the temperature scale on the chlorine pressure gauge will disclose that the equilibrium (evaporating) temperature for a pressure of 85 psi is 70 degrees F. Since the actual gas temperature is 87 degrees F, the superheat is 17 degrees. It will be observed that a decrease in the withdrawal rate will result in an increase in superheat. Likewise, increasing the withdrawal rate will result in a decrease in superheat.

In general, as long as there is some superheat, the evaporator is functioning properly. By periodically recording the superheat at a given chlorine feed rate and water bath temperature, the plant operator has an indication of the condition of the inside of the chlorine cylinder. Contaminants in the liquid chlorine tend to accumulate in the evaporator cylinder and deposit on the inside wall, thus, reducing heat transfer from the water bath. When sufficient impurities have collected to result in insufficient heat transfer, the superheat will have dropped close to zero and liquid chlorine will begin passing through the evaporator outlet.

Therefore, a periodic record of superheat will permit the operator to schedule the cleaning of his evaporator well in advance. As noted previously, the evaporator is functioning properly as long as there is some superheat. However, due to tolerance in gauges, the first cleaning of a new evaporator should be scheduled when the superheat has dropped to about 10 degrees F. Examination of the interior of the cylinder when the heat is removed for cleaning can guide the operator in judging what value of superheat should be used as a criterion for further cleanings.

EVAPORATOR SAFETY ALARM SYSTEMS

Various alarms monitor evaporator performance, i.e. high and low temperature, water level and over pressure conditions. Evaporator systems are fed by 907 kg containers or tank car supplies.

SUBJECT:

CHLORINATION EQUIPMENT

TOPIC: 4

DESCRIPTION AND OPERATION OF GAS CHLORINATORS

OBJECTIVES:

The trainee will describe the normal operation of the following chlorination systems:

1. Advance
2. Wallace & Tiernan
3. Fischer & Porter

OPERATION OF GAS CHLORINATORS

GENERAL

Although the suppliers of chlorination equipment produce a seemingly endless array of models and control systems to handle all possible combinations of operating conditions in water and wastewater treatment plants, we will use only three models to represent all of the industry. Since the operating principles of many of the models are similar and since we could not hope to do justice to all the systems in the limited space available here, we will draw comparisons between models and highlight one model to represent an operating system including competitive models.

This should in no way be construed as an endorsement of any particular brand or model by the Ontario Ministry of the Environment or by its Training and Certification Section.

A large number of the installations in this Province are represented by the low-to-medium capacity, "modular" type of chlorinator. These models are most often installed as a cylinder, scale or wall-mounted vacuum regulator unit with a remotely - mounted injector. By changing some of the body parts or attached components, these chlorinators can be engineered to efficiently achieve feed rates as low as 1 kg per day or as high as 225 kg/day, (2-500 lb/day) with manual or in some cases automatic feed rate control.

These models are occasionally mounted in cabinets to conform with the appearance of other process equipment but this does not alter their capacity or operating principle. The model line that we have illustrated to represent this generic group of chlorinators is the Advance 200 Series of models.

For the medium-to-high capacity range, we have used two models to illustrate the "discrete component". The Wallace and Tiernan (W & T) V-Notch and the Fischer and Porter Gas Dispenser. Both of these model lines offer feed rates as high as 4500 kg/day (10,000 lb/day) with compound loop automatic control and are representative of similar models available from other suppliers.

COMMON COMPONENTS

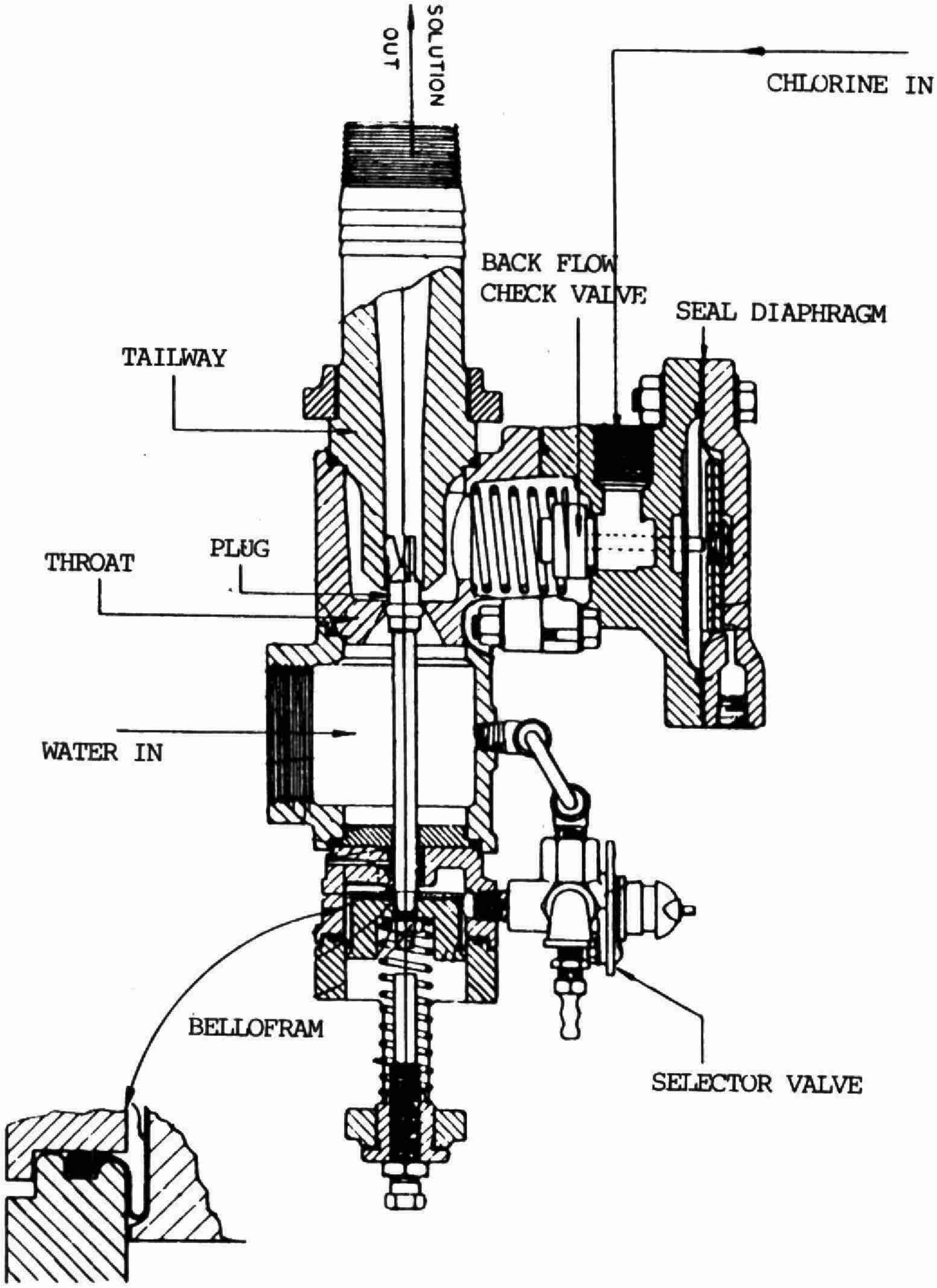
Injector/Ejector

The water-operated injector or ejector (Figure 4-1) consists of a venturi-type nozzle and a diaphragm or ball-type check valve. Water enters the venturi under high pressure, low velocity. At the "neck" or nozzle, this changes to low pressure, high velocity, thereby creating a partial vacuum. This vacuum draws chlorine gas into the venturi, and the solution of chlorine and water is then discharged to the point of application.

The injector is the first point in the process where the chlorine gas comes into contact with the water. Total mixture of the solution usually occurs at or beyond the injector discharge.

A back-flow check valve (Figure 4-1) connected to the injector is used primarily to prevent any solution from backing up into the chlorine line, leading to possible corrosion of materials.

Should an accident occur while the operation is under proper vacuum, air would be drawn into the chlorinator, thus preventing chlorine from reaching the atmosphere. Negative or low pressure permits the use of lighter, corrosion-resistant plastic components. If chlorine is under any pressure, plastic components must not be used.



CUT-AWAY VIEW INJECTOR

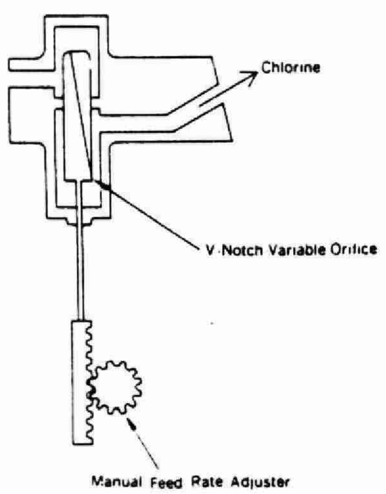
FIGURE 4-1

The injector may wear with time. If the raw water contains any foreign matter, a strainer should be installed in the water line to the injector. The injector does NOT have to be installed in the cabinet with the chlorinator but may be located wherever it is convenient. It is usually desirable to have the injector installed as close to the point of chlorine application as possible. This will result in reduced back-pressure at the injector because of shorter chlorine solution piping.

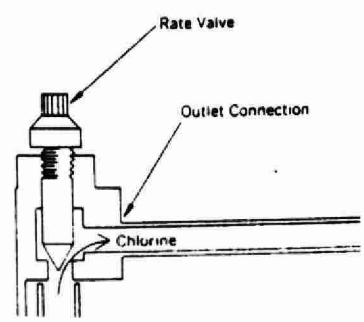
Variable Orifice

The variable orifice (Figure 4-2) is the part of the chlorinator which controls the flow of chlorine through the chlorinator. The orifice can be adjusted manually or automatically and its setting will depend on the chlorine demand in the water or wastewater process. There are different types of orifices available, as indicated in Figure 4-2.

Variable Orifice



V- NOTCH VARIABLE ORIFICE.



RATE OR NEEDLE VALVE.

Figure 4-2 TYPES OF VARIABLE ORIFICE CONTROL

ADVANCE 200 SERIES CHLORINATOR

Operation

Figure 4-3 illustrates the flow diagram for the Advance Chlorinator. Water passing through the injector under pressure at point (A) forms a vacuum and causes diaphragm (B) to be pulled away from the seat. This allows the vacuum to be transmitted to the rate valve (C). If the rate valve is open, the vacuum is transmitted through the rate indicator (D) to the regulating assembly (E). This pulls the regulating diaphragm in regulating assembly (E) towards the chlorine inlet valve (F), opening it and allowing chlorine gas to enter the system and pass through (E), (D), (C), (B) to (A) where it is mixed with water and discharged to the point of application.

Vacuum failure allows the spring on the inlet valve (F) to move the diaphragm (E) away from the valve (F), closing valve (F) and stopping the flow of chlorine.

If valve (F) should "stick" in the open position, diaphragm (E) would be forced away from the stem of valve (F) and chlorine would pass through the centre of diaphragm (E) and out through the vent connection to the atmosphere.

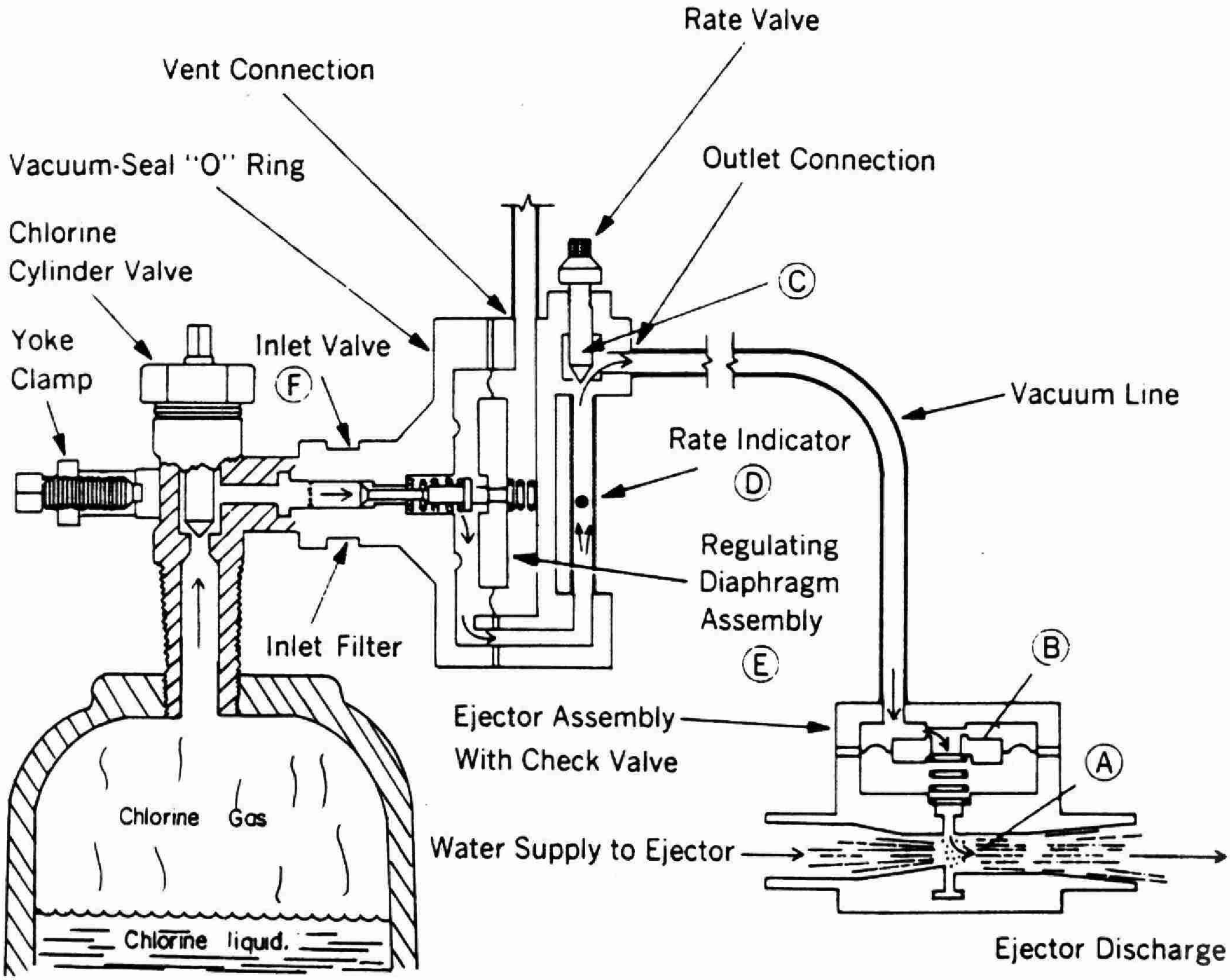


FIGURE 4-3 ADVANCE GAS CHLORINATOR

WALLACE AND TIERNAN (W&T) V-NOTCH CHLORINATOR

Components

Figure 4-5 shows a diagram of the W & T Variable Vacuum Chlorinator and its principle components.

Chlorine Pressure Regulating Valve (CPRV)

On leaving the header, the gaseous chlorine enters the chlorinator through the CPRV (See Figure 4-4). The CPRV is a diaphragm valve which works against a spring force. It maintains the proper operating vacuum ahead of the variable orifice. The vacuum in the chlorinator must be greater than the spring force in the CPRV to draw chlorine gas into the chlorinator. The vacuum pulls the diaphragm and stem down; chlorine gas flows through the feed rate indicator at the indicated pound per day setting. The spring force in the CPRV controls absolute pressure (or vacuum) in the regulating valve.

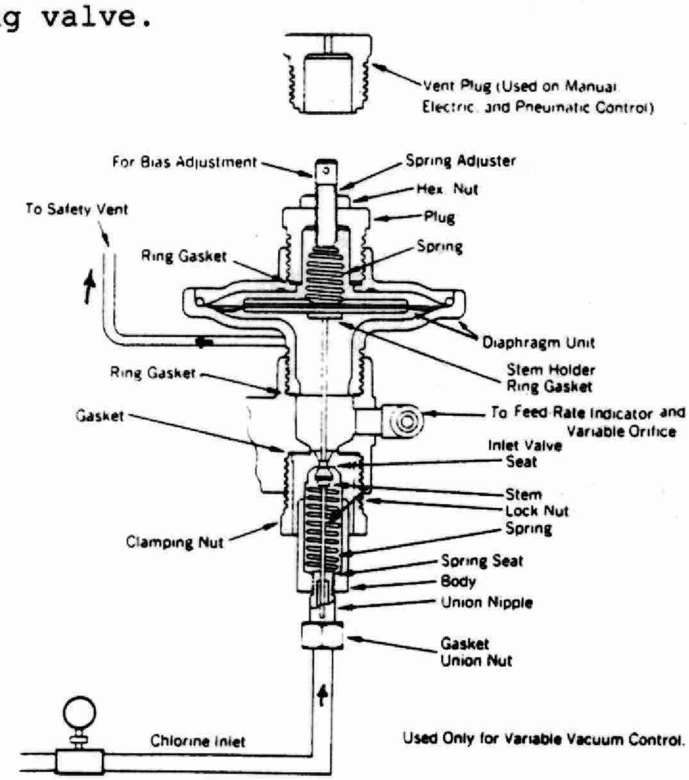


Figure 4-4 CHLORINE PRESSURE REGULATING VALVE

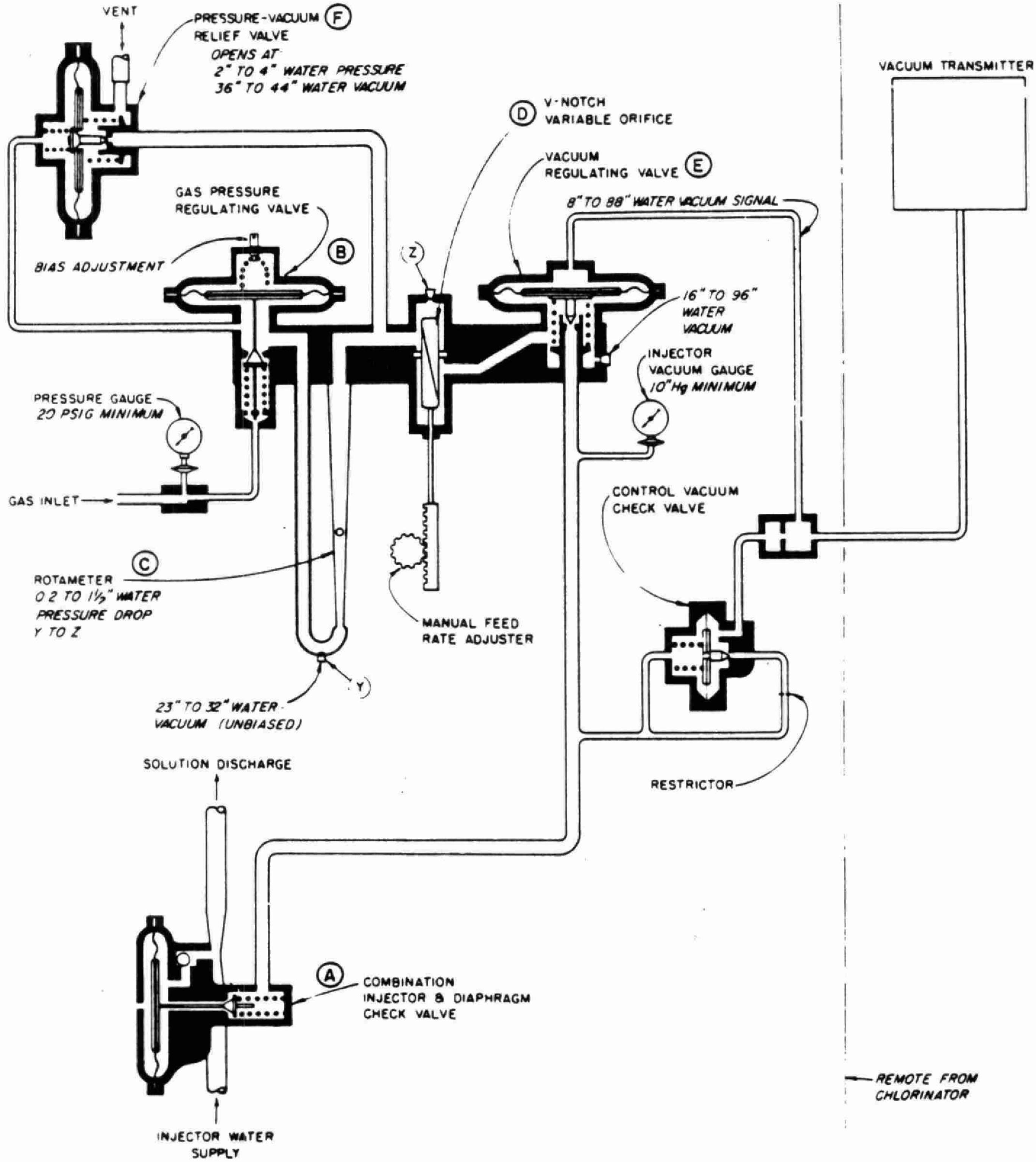


Figure 4-5 W&T V-NOTCH CHLORINATOR

Feed Rate Indicator (or Rotameter)

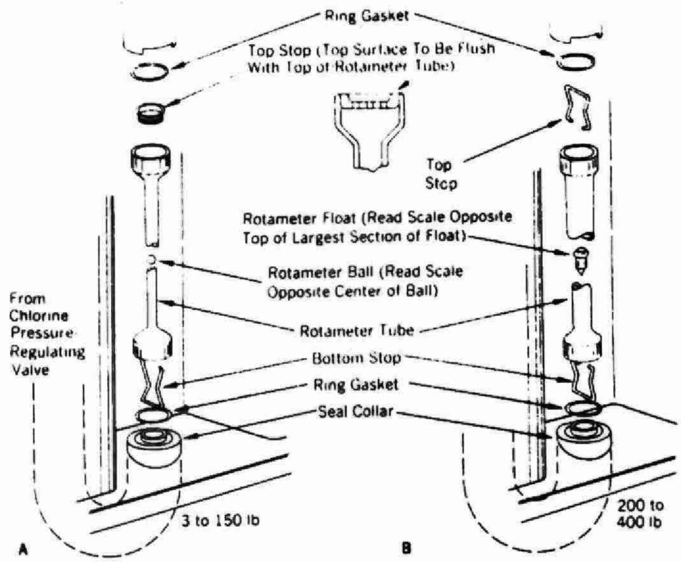


Figure 4-6 ROTAMETER

The feed rate indicator, or rotameter (See Figure 4-6) is a tapered glass tube with a round ball inside. The ball will position itself in the rotameter according to the chlorine gas flow. The size of the glass tube depends on the gas flow required. When operating normally, the ball is free to rotate inside the tube. If it is not rotating, the ball is stuck against the inner walls of the tube because the inner walls are dirty. Use trichloroethylene to clean the rotameter.

Gas flow readings are taken across the <u>centre</u> of the ball, not across the top or the bottom. Other types of floats are also used, and will depend on the size of chlorinator and the gas flow through the unit. The point of reading on a float will depend on the manufacturer. Read his instructions. The feed rate indicator tube and float are pre-determined for a specific maximum capacity and cannot be interchanged. For example, a float from a 10 kg/day maximum capacity rotameter cannot be used in a 20 kg/day maximum capacity tube.

Pressure-Vacuum Relief Valve

The pressure-vacuum relief valve (Figure 4-7) is a diaphragm-operated two-way spring-loaded valve and is used to provide vacuum relief in the chlorinator system or draw air into the chlorinator. It prevents a build-up of vacuum which could damage the unit, and vents chlorine to the atmosphere if there are problems in the chlorine pressure regulating valve.

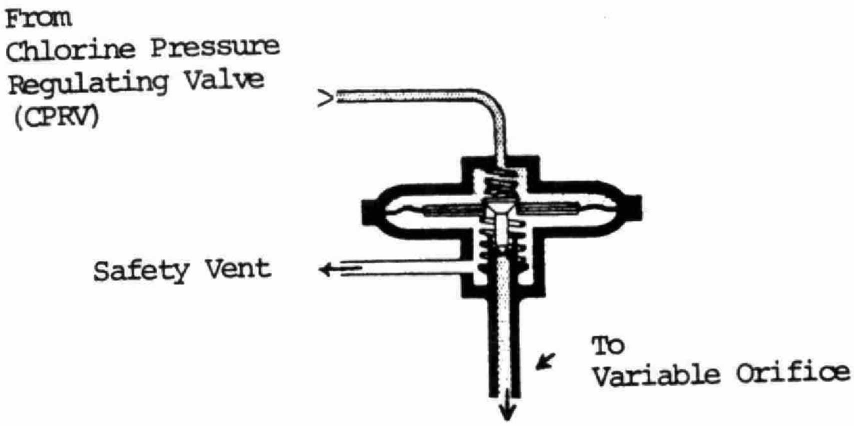


FIGURE 4-7 PRESSURE VACUUM RELIEF VALVE

Vacuum Regulating Valve

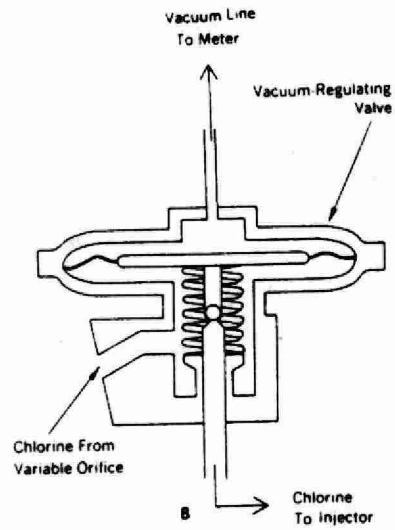


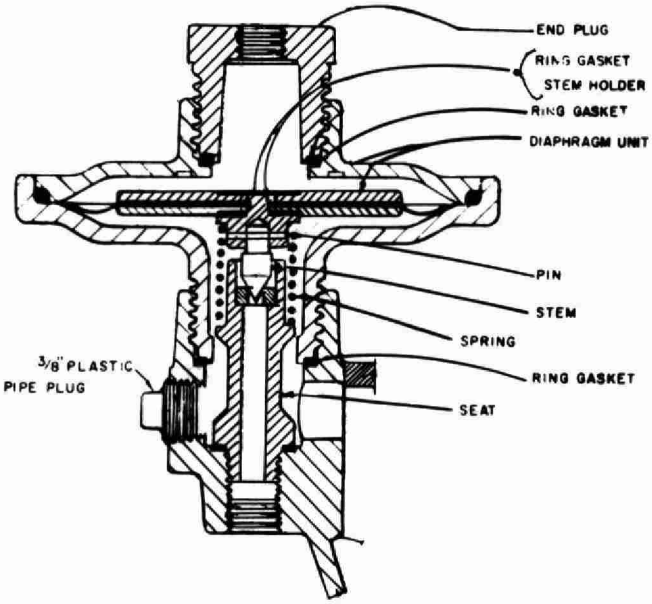
FIGURE 4-8 VACUUM REGULATING VALVE

The diaphragm spring-loaded vacuum regulating valve (Figures 4-8 and 4-9) maintains the proper operating vacuum downstream of the variable orifice. Chlorine passes through the vacuum regulating valve to the injector.

Operation (See Figure 4-5)

A controlled vacuum is developed by an injector (A), allowing the chlorine gas to enter the chlorinator through a spring-loaded, diaphragm-operated pressure regulating valve (B). This valve maintains the proper operating vacuum ahead of the variable orifice (D).

The gas then flows through a rate of feed indicator (C), by-passes a combination vacuum and pressure relief valve (F), passes through the variable orifice (D), and finally through a vacuum regulating valve (E), which maintains the proper operating vacuum downstream of the variable orifice.



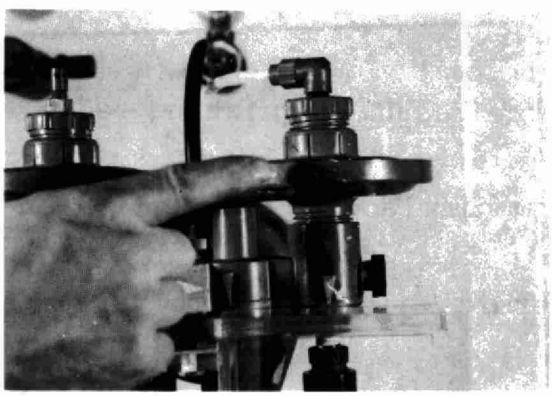


Figure 4-9 VACUUM REGULATING VALVE
180 KG CAPACITY CHLORINATOR

The gas then passes to the injector (A) where it is dissolved in water. The resultant solution is discharged from the injector to the point of application via a solution tube or diffuser. The feed rate is adjusted by changing the area of the variable orifice. This is accomplished by positioning the control plug (V-notch) within the seat.

The chlorine pressure regulating valve, which regulates the vacuum ahead of the metering orifice, also shuts off the chlorine if interruption of the injector water supply should destroy the operating vacuum, or a leak should develop in the vacuum line. Intermittent start-stop or program operation is obtained by interrupting the injector water supply.

Remote Vacuum Chlorinator

This is a newly introduced system and requires a separate description. The system operates under a vacuum produced at the aspirator-type injector. Vacuum is transmitted to the control module and then to the vacuum-regulating valve by plastic pipe or tubing.

Gas enters the vacuum-regulating valve. Here a diaphragm senses vacuum on one side and atmospheric pressure on the other. Force on the diaphragm displaces a spring-loaded stem off a seat. This tends to maintain the proper operating vacuum ahead of the control module and permits gas to flow toward the control module.

Still under vacuum, gas enters the control module. Its flow rate is measured as it passes through the rotameter and controlled at the V-notch by changing orifice area. At this point, gas flow is controlled by a differential-regulating valve. This valve maintains a constant differential across the V-notch.

Gas next passes to the injector. At the injector, metered gas is dissolved in the water stream. The resultant solution is discharged to the point of application. In larger machines there are additional components.

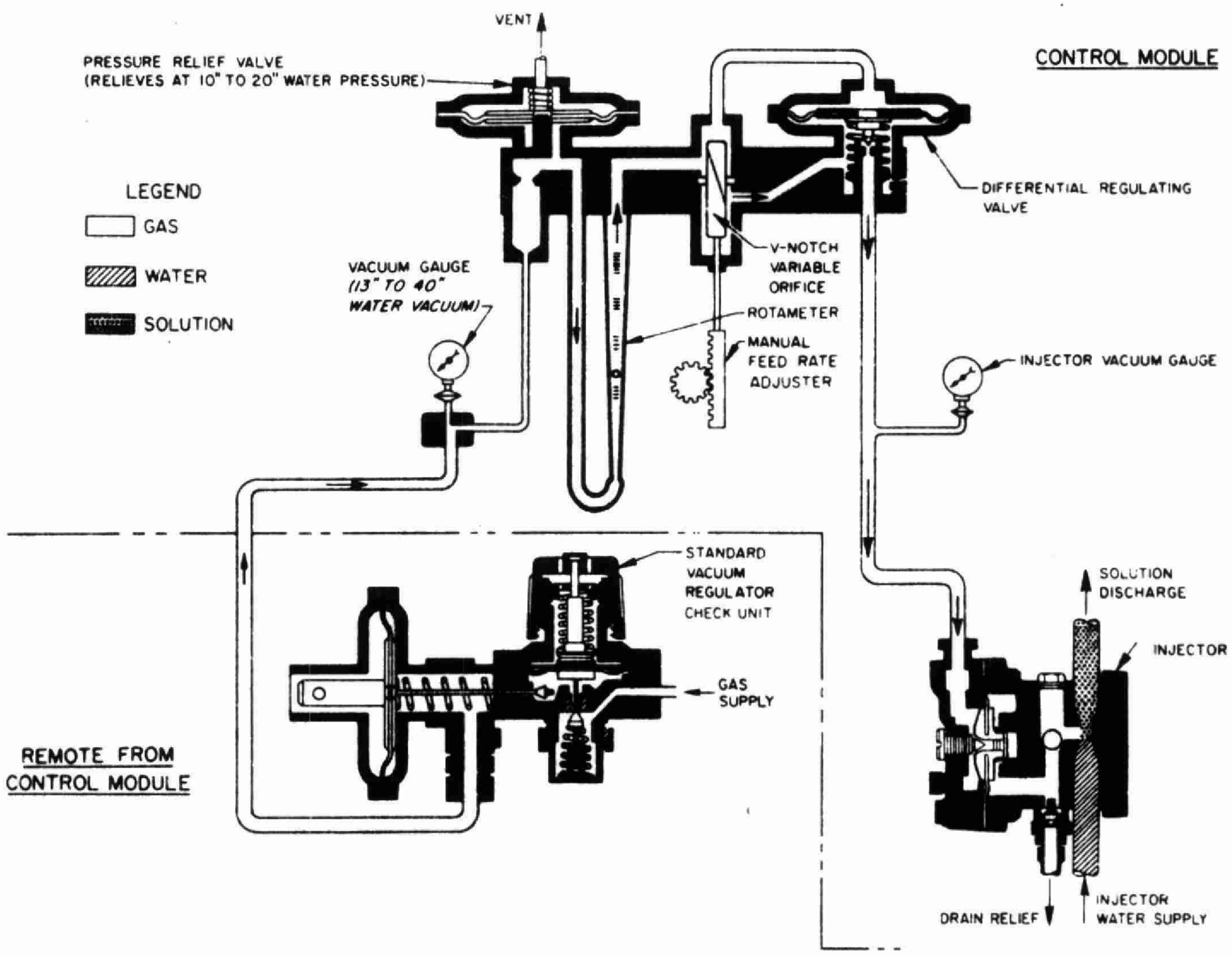


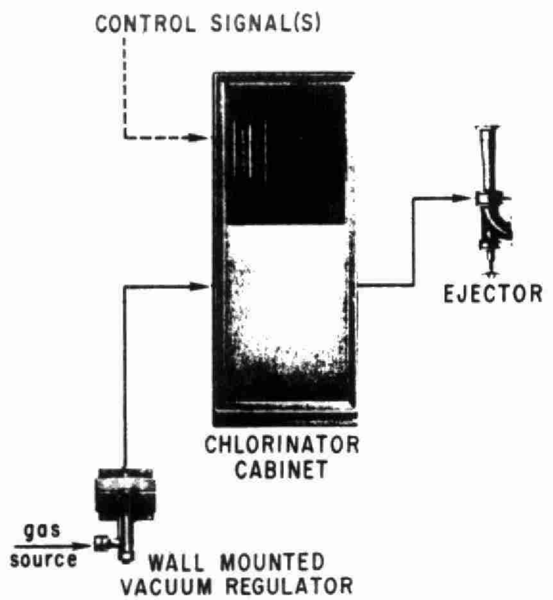
Figure 4-10 Remote Vacuum Chlorinator Flow Diagram

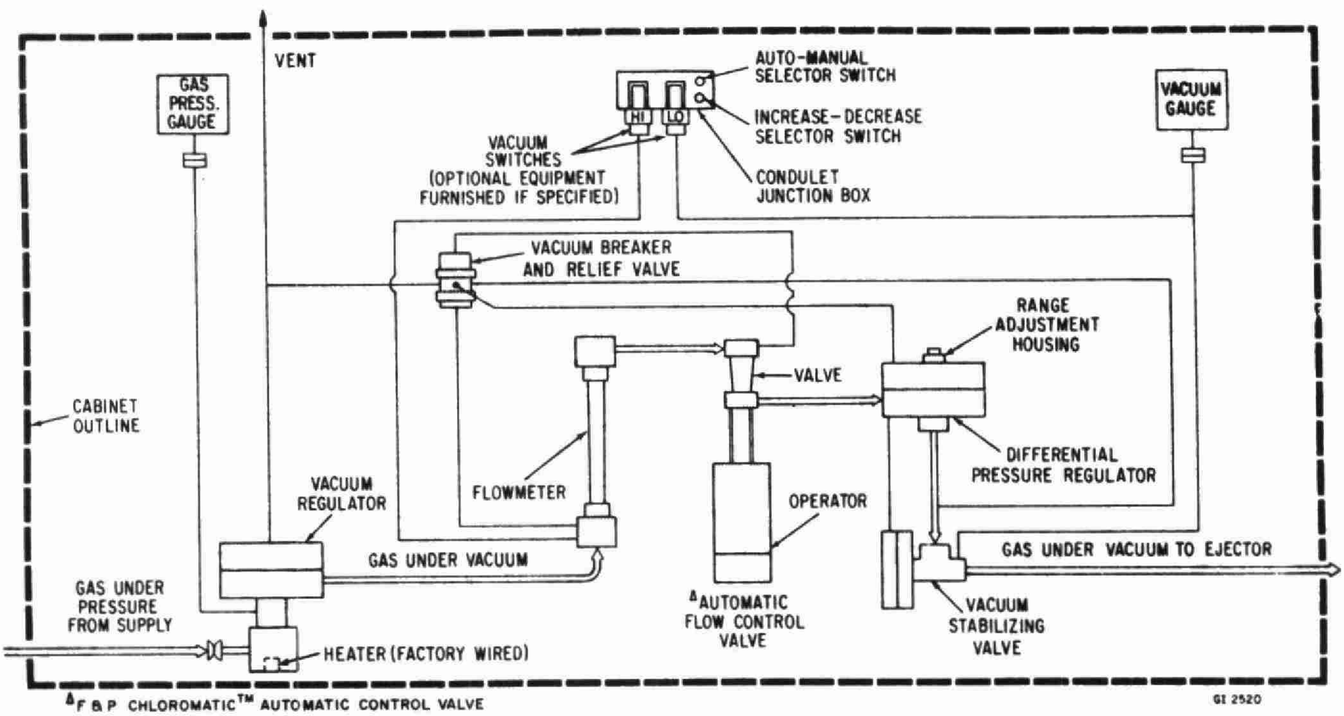
FISCHER & PORTER CHLORINATOR

General Description

This type gas dispenser uses a vacuum-actuated, spring-loaded regulating valve to reduce the gas from a varying supply pressure to a constantly regulated vacuum, usually about 20 inches water column. Operating vacuum is created by a companion water jet aspirator, commonly called an ejector. The gas, then, is actually "pulled" through the various components of the dispenser and into the ejector where it is thoroughly mixed with the water (or process liquid) to form a chemical solution. This solution is then delivered via suitable rigid or flexible piping to the main flow of process liquid at the desired point of chemical solution application.

Vacuum operated, solution feed type gas dispensers are by far the most commonly used because of their intrinsically safe operating feature, e.g., gas flow from the supply system is automatically shut off by the closure of the vacuum-actuated, spring-loaded regulating valve in the event of loss of operating vacuum for any reason.





VACUUM REGULATION—INTERNAL

Figure 4-11 FISCHER & PORTER CHLORINATOR
UPPER - SHOWING INSTALLATION
LOWER - CABINET INTERIOR

SUBJECT: CHLORINATION EQUIPMENT

TOPIC: 5 CONTROL SYSTEMS

OBJECTIVES:

1. Recall the types of chlorine control systems and the use of each.

2. Describe the chlorine control system.

3. Recall the purpose of:

   a) The Residual Analyzer Recorder

   b) The Residual Recorder Controller

TYPES OF CONTROL SYSTEMS

The chlorine control systems available include:

1. Manual system
2. Flow proportional or open loop control
3. Direct residual or closed loop control
4. Compound loop control

Manual System

1. The rate of feed is varied by hand.
2. It is only suitable at points: (i) where flow of sewage or water to be treated is constant, (ii) where the flow rate is changed manually (eg. when starting a second pump), at which time chlorination feed can be adjusted to the new flow.

Flow Proportional or Open Loop Control (See Figures 5-1, 5-2)

In the flow proportional or open loop control system:

1. An adjustment is made in accordance with a command signal from the flow meter or pump starter. Response is *assumed* to be correct.
2. Any signal from a primary measuring device (orifice, venturi, etc.) can be fed directly or converted to proper form by a *transducer* to allow electric or pneumatic positioning of chlorinator control units.

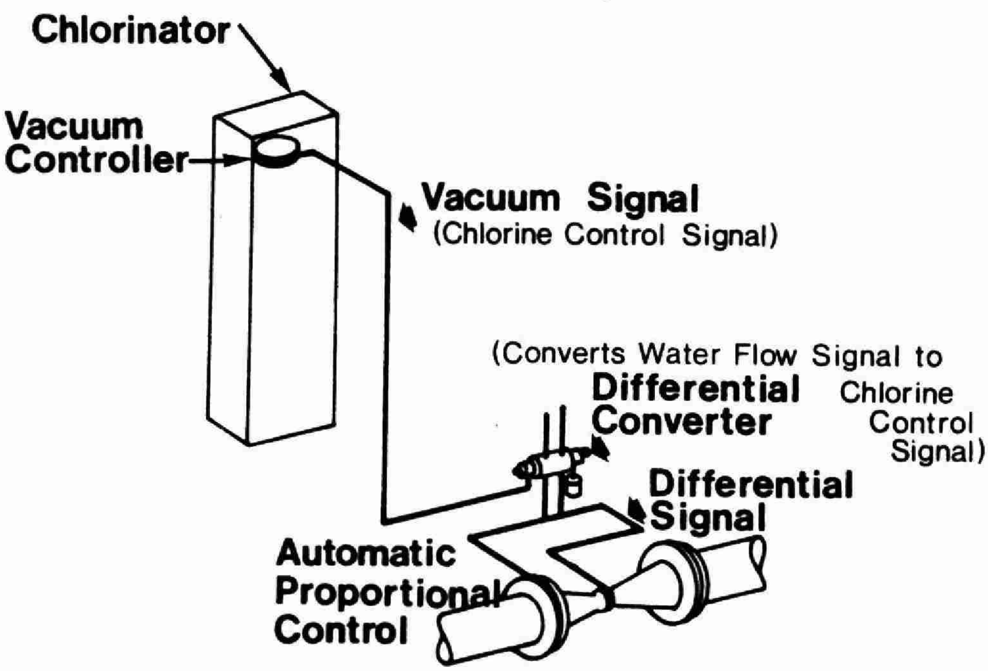


Figure 5-1

OPEN LOOP CONTROL

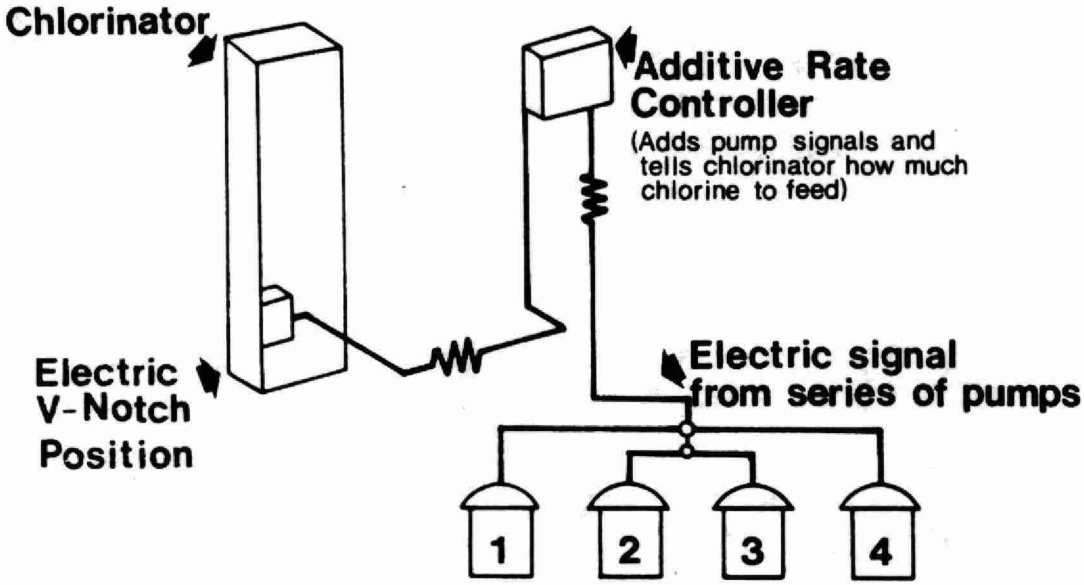


Figure 5-2 OPEN LOOP CONTROL

Note: When flow varies and chlorine requirements remain constant, flow proportional or open loop chlorination control is used.

<u>Direct Residual or Closed Loop Control</u> (See Figure 5-3)

The direct residual or closed loop control system operates as follows:

1. A sample of chlorinated water is continuously withdrawn downstream from point of chlorination and analysed. (See Page 5-5 for information on the Chlorine Residual Analyzer).

2. The recorder compares the *measured* residual with the *desired* or set residual to see if the chlorine feed rate should be increased or decreased. It then sends a signal to the chlorinator control device to make the change.

3. Types of signals used include:

   (i) an electric signal
   (ii) a pneumatic signal
   (iii) a vacuum signal

Note: *When flow remains constant, but chlorine requirements do not, direct residual control is used.*

Why is it called a closed loop?

Measurement of end result is made and information is fed back to the chlorinator control for comparison with control set point.

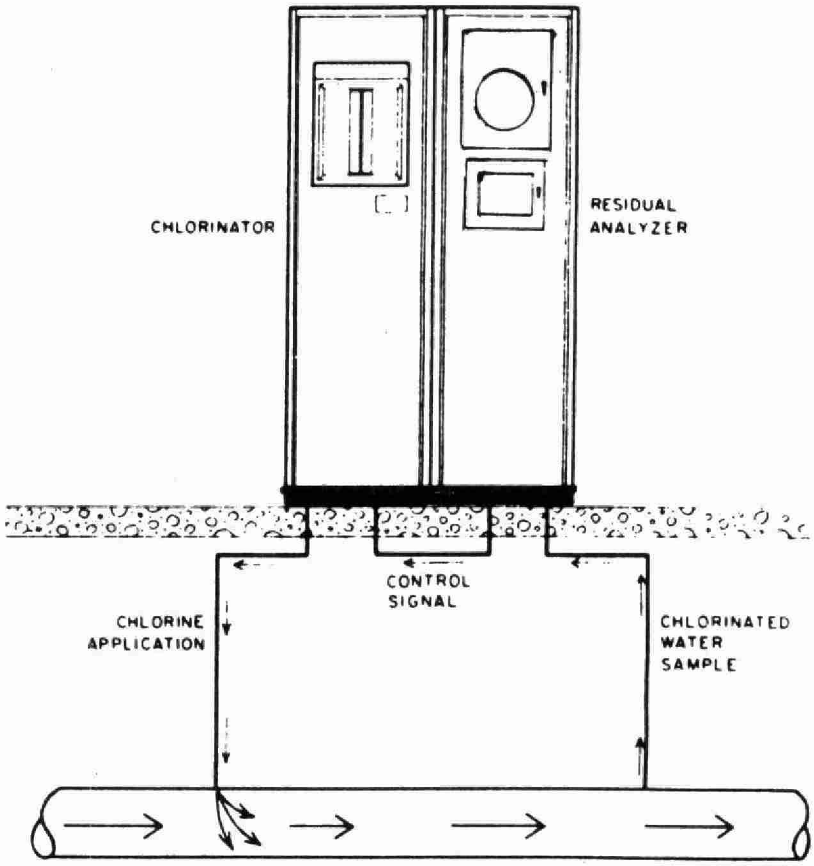


Figure 5-3 CLOSED LOOP CONTROL

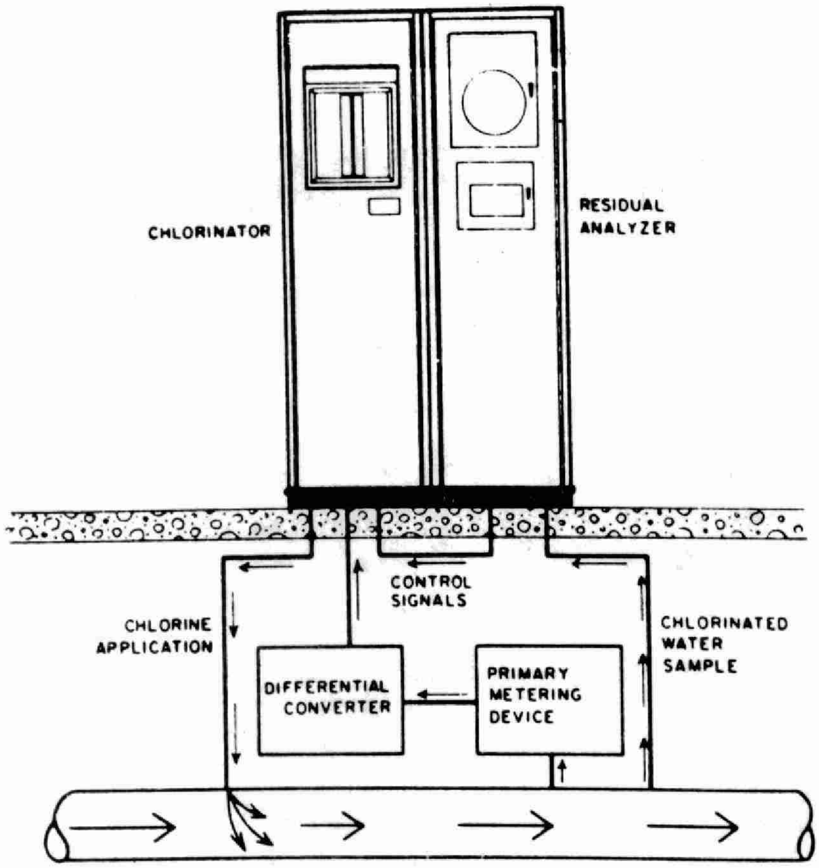


Figure 5-4 COMPOUND LOOP CONTROL

Compound Loop Control (See Figure 5-4)

The compound loop control system is a combination of open loop and closed loop systems. When flow increases, the chlorinator adds the correct amount of chlorine to keep the present dosage level. A sample is withdrawn downstream and analyzed to determine if chlorine demand has changed. If so, information is relayed back to the chlorinator and correction in dosage is made according to the new chlorine demand.

Note: When both flow and chlorine requirements may vary, compound loop chlorination control is used to maintain desired residual of chlorine in water.

RESIDUAL ANALYZER RECORDER

Purpose

The purpose of the residual recorder is to indicate and record the residual of chlorine in a plant discharge/or at any point within the plant. (See Figures 5-5 and 5-6)

Principle of Operation

A controlled sample of water is fed into a cell.

A buffer solution or CO_2 gas is added to maintain the pH within a pre-determined range.

The presence of chlorine in the water sample acts as an electrolyte and causes a small D.C. electrical current which is proportional to the amount of chlorine in the sample.

This is basically a **titrator** working on a continuous basis.

The small electrical current generated by the cell assembly (analyzer) is fed into an amplifier system and changed to a control voltage to activate a servo motor. The servo motor drives a gear train to position the pen on the chart and the feed-back potentiometer in the balancing circuit until the control voltage and balancing voltage are equal. At this point, the motor stops.

An increase or decrease in the chlorine residual of the water entering the cell will cause a corresponding change in the position of the pen on the chart.

The operation of this unit must be checked daily or weekly (as experience will dictate). It can only be checked accurately with the use of an amperometric titrator (See Topic 11).

The residual recorder can be used to record either free or total chlorine residual.

In some cases where the pH of the water is within certain limits, a buffer solution is not required.

Chlorine Residual Alarms

Chlorine residual alarms can be activated by the use of electrical contacts adjustable to any point within the range of movement of the pen. These contacts activate a relay to pull in an alarm system, and will not handle the amperage required to operate the alarms.

RESIDUAL RECORDER CONTROLLER

Purpose

The residual recorder controller continuously indicates and records the residual of water, and raises or lowers the chlorinator setting accordingly.

Principle of Operation

This equipment is exactly the same as described under "Residual Recorder" with the addition of electrical contacts and "set point" control, plus relays, to control the increase or decrease of the chlorinator feed.

The residual recorder controller allows a "loop system" for automatic control in a plant (See Figure 5-4).

Maintenance Problems

The time involved in the transfer of water and sample through the control loop system is critical. The manufacturer's specifications must be followed very closely to set up and regulate the equipment for the best operating conditions in the treatment plant.

Maintenance

1. Clean the cell assembly as required by the suggested maintenance program and/or as dictated by operating conditions. Use the method, materials, etc., described in the manufacturer's specifications.
2. Regularly inspect the leads from the cell (analyzer) to the recorder unit for possible corrosion. This is particularly important for older models of equipment.
3. Clean the electrical contacts whenever they look dirty or seem unreliable.
4. Use a voltmeter with a low range D.C. millivolt scale to indicate whether or not:
   a) the cell and electrode assembly is producing an electrical signal,
   b) the amplifier is converting this signal to the motor requirements.

Also use a voltmeter to verify if the contacts are energizing the required alarm or control circuits. The manufacturer's electrical drawings will indicate where to check this, and what voltage readings to expect.

5. When taking gears or mechanical linkages apart, mark them with check lines to simplify reassembling into their original positions.

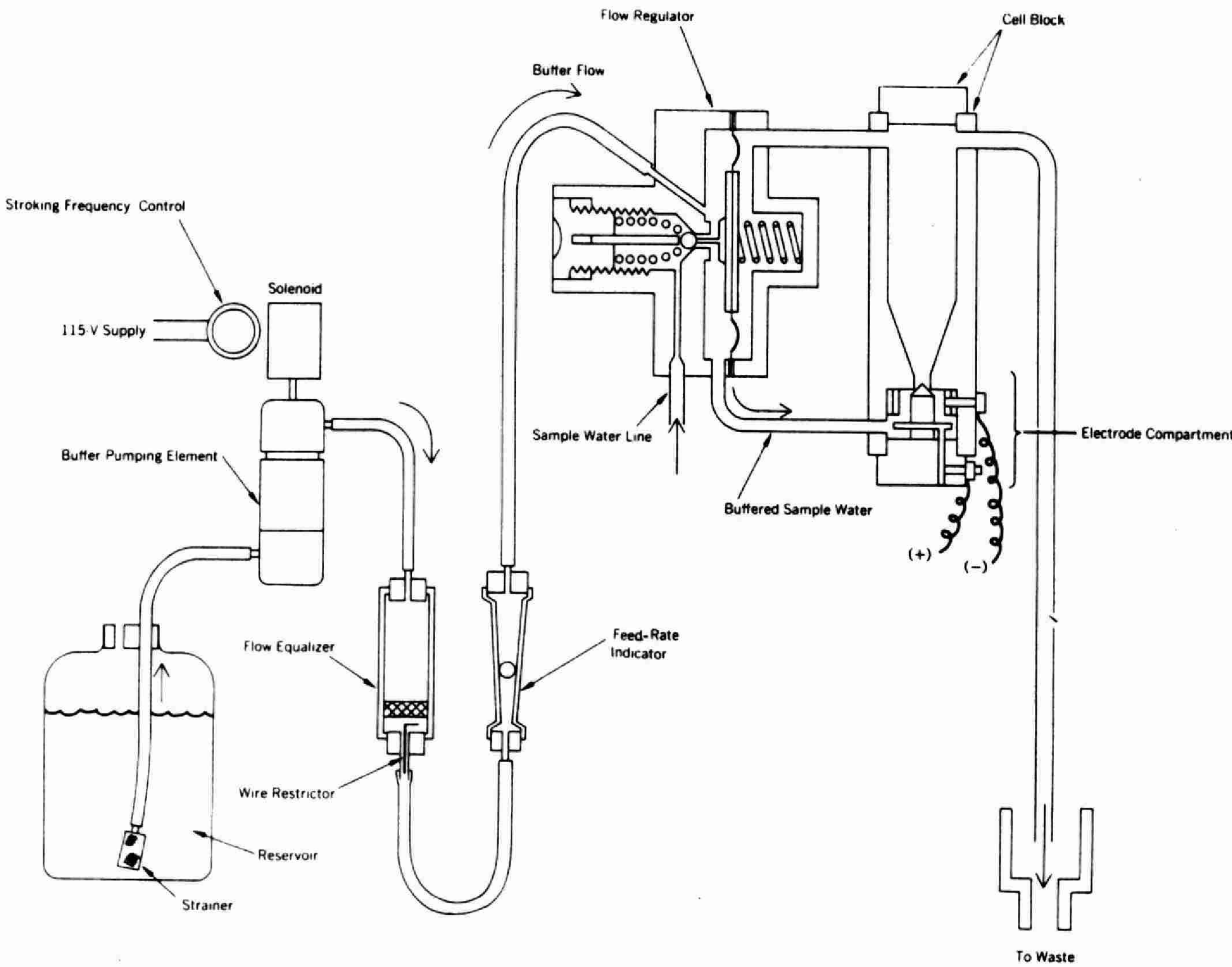


Figure 5-5 RESIDUAL CHLORINE SAMPLING CELL FOR WATER

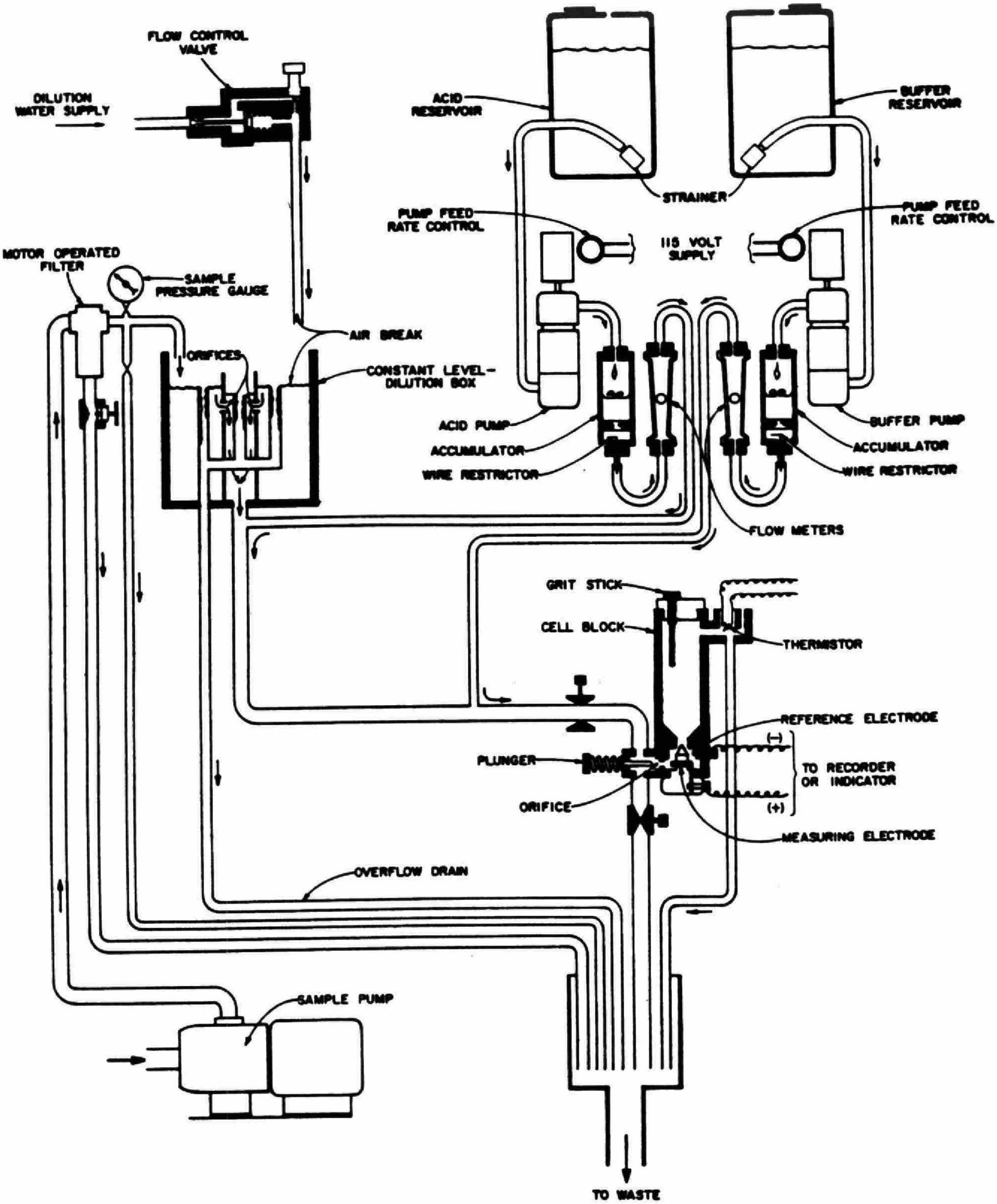


Figure 5-6 RESIDUAL CHLORINE ANALYZER
FOR WASTEWATER OR INDUSTRIAL WASTE

Recording Chart and Pen (See Figure 5-7)

A recording chart is used to record the daily consumption of chlorine. When positioned, the chart must be free to move, not binding in any way. When changing charts, always check the time to make sure the chlorine consumption is recorded at the proper hour on the chart.

Chart pens are supplied with ink by cartridge.

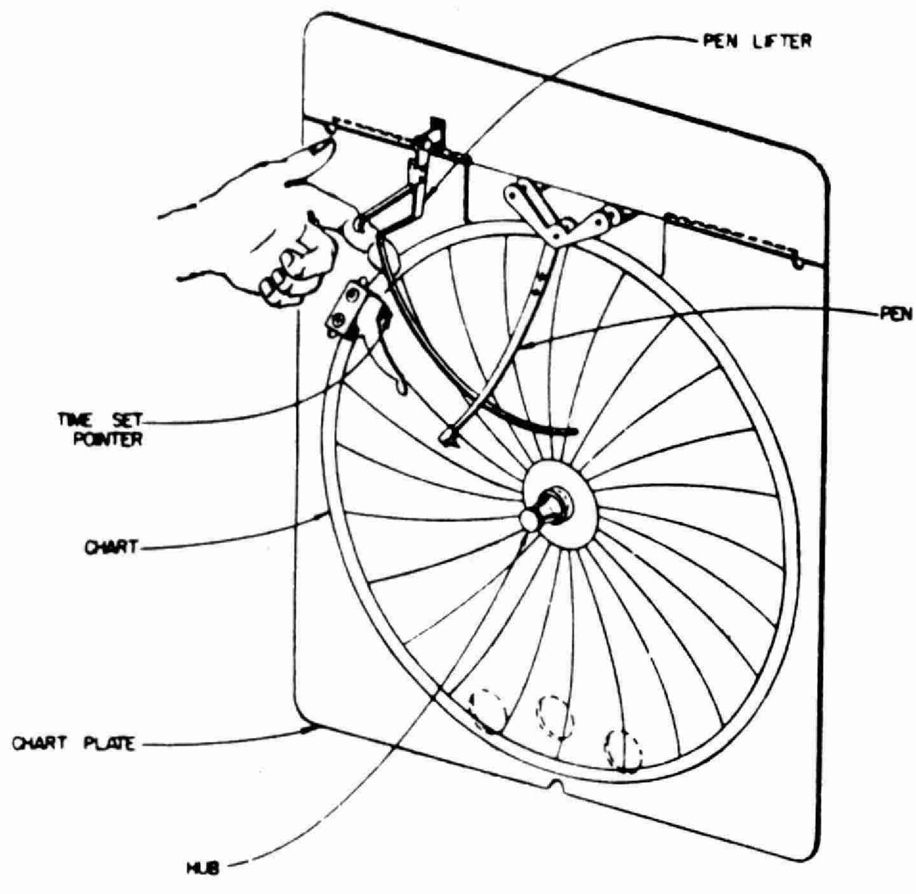


Figure 5-7 RECORDING CHART

SUBJECT:

CHLORINATION SYSTEM OPERATIONS

TOPIC: 6

SAFETY PRACTICES

OBJECTIVES:

The trainee will be able to

1. Recall the hazards associated with chlorine.
2. Recall the general safety procedure if a leak is detected.
3. Describe the remedies for
   a) liquid leaks from cylinders
   b) leak at the valve packing
   c) leak at a fusible plug.
4. Recall the purpose of rupture discs.
5. Recall the safety procedures in emergency situations.
6. Demonstrate the use of the 15 minute air pack.
7. Demonstrate and/or describe the first aid procedures used in handling casualties resulting from exposure to chlorine.

SAFETY PRACTICES

GENERAL

Chlorine is a potential killer when the chlorine handling equipment, although well designed, becomes defective or when people become careless. Even when all regulations are observed, safety practices followed and well-trained crews are employed, there is still a chance that an accident will occur.

Be prepared for emergencies - hold periodic emergency drills to familiarize your personnel on how to handle chlorine emergencies. Practise donning self contained breathing apparatus (SCBA) and ensure the air cylinders are full. Each plant should have spare, full cylinders.

To avoid accidents when working with chlorine, follow the safety procedures carefully. In the event of a mistake or accident, however, SCBA's should be available so that emergency measures can be taken. The chlorinating room itself should be adequately ventilated with a separate ventilating system capable of removing the air from the room once every four minutes. This ventilation should be located at a low level in the room because the chlorine gas is heavier than air. Any room with chlorine containers should have two exits and the doors should open outwards for easy escape. SCBA's to be located just outside the chlorinating room (at least one unit within 4.5 m) as should the switches for the ventilating system and lights.

Chlorine can be detected by equipment or even by smell in very small dosages. The least amount of chlorine in the atmosphere detectable by smell is about 3.5 mg/L and when this occurs, the operator should be alerted to potential hazards, such as leaks or faulty equipment. At high concentrations, chlorine

will affect the body. Appendix A discusses chlorine detection using installed alarm systems.

Because higher concentrations of chlorine cause irritation of eyes, coughing and laboured breathing, it is unlikely that any person would remain unprotected in a contaminated area **unless he were unconscious or trapped.** The symptoms of advanced stages of exposure are retching and vomiting followed by difficult breathing. In extreme cases, the difficulty with breathing may increase to a point where death can occur from suffocation.

The maximum amount that can be inhaled for one hour without serious effects is about four (4) mg/L. At fifteen (15) mg/L chlorine will cause irritation of the throat; at thirty (30) mg/L it will cause serious coughing spells; and at forty (40) to sixty (60) mg/L it is extremely dangerous for one-half hour exposure. A few breaths of air containing 1,000 mg/L <u>may</u> kill a <u>man</u>.

TABLE No. 6-1

WARNING - THE EFFECTS OF CHLORINE GAS

	Chlorine (mg/L)	
You can breathe no more than	4.0	safely for 1 hour
It will take at least	1.0	for several hours before you show symptoms of poisoning
	3.5	before you can smell it
	15.1	to cause throat irritation
	30.2	to make you cough
	40-60	to be dangerous in 30-60 minutes
	1000	to kill you in a few breaths

Standard Safety Practices

1. Practise personal hygiene. See Appendix B.

2. Always wear a face shield and chemically resistant gloves.

3. Always turn on the chlorine exhaust fan when entering the chlorine room.

4. All persons using the gas protective equipment must be trained in its use and maintenance.

5. Do not start up or operate a chlorinator or turn on a cylinder unless adequate protective equipment (SCBA) is available.

6. Ensure a full self-contained breathing apparatus is near by prior to starting or operating a chlorinator or performing work other than routine inspection or housekeeping. If a chlorine leak occurs, leave the room IMMEDIATELY. Re-entry shall be made only when two persons are present and both are wearing a self-contained breathing apparatus (SCBA) and protective clothing.

7. Never perform work on chlorine lines or equipment while alone. A minimum of two persons must be present at all times when work is being performed.

8. A self-contained air breathing unit must not be used unless the air cylinder is fully charged. **Air cylinders must be completely recharged after each use.**

9. Never apply water to a chlorine leak because of the added corrosive action created by the water and chlorine mixture.

10. All removable parts of the chlorinator such as cylinder clamps, metal hose connections, couplings, headers, valves, etc., should be removed at the end of the chlorinating season, cleaned and inspected, and worn and damaged pieces replaced.

TYPES OF LEAKS ENCOUNTERED - AND THEIR REMEDIES

Liquid Leak

One basic and very important rule when dealing with chlorine leaks is always to keep the leak in the vapour phase. This is usually quite simple in the case of "150-lb." cylinders, since they are stored and usually used in an upright position. With "one-ton" cylinders, however, liquid chlorine could easily leak through a valve or a fusible plug. Liquid chlorine will vaporize to approximately 460 times its volume as a gas.

The leak will be greatly reduced by rolling the tonner (if possible) into a position where gas is escaping instead of the liquid chlorine. As the gas escapes, the liquid will refrigerate itself, lowering the vapour pressure.

Leak at Valve Packing

This can be caused by dried-out packings. In this case, chlorine will be coming out around the valve system and cannot be stopped by tightening down the packing gland nut. This should only occur when valve is opened.

If leak is very slight, hook up cylinder and start drawing chlorine at maximum rate. This should quickly reduce the pressure and probably stop the leak. If leak is of major proportions and does not respond to this treatment:

- shut off valve
- set cylinder outdoors **in the shade**
- call supplier who will pick up cylinder or replace the packing.

Leak at Fusible Plug

This is usually due to corrosion from moisture, either internally or from the outside.

1. Cylinders

   One manufacturer has a special clamp with a rubber pad and steel backing which easily controls this type of leak. The adapter clamp can also be used to stop this type of leak. Take a flat file and file the area around the fusible plug flat. Apply a small patch of synthetic rubber gasket material with a follow-up piece of metal and clamp this firmly in place.

   NOTE:

   This emergency device now leaves the cylinder without protection from high temperatures. Use up the chlorine in the cylinder as rapidly as possible.

2. 907 kg Container (Tonner)

   a) Leak can be at the fusible metal plug or at the threads around the plug. If leak is through the fusible plug, there is a special clamp of rubber and steel which readily controls the leak. If the leak is around threading of the fusible plug, the Chlorine Institute emergency kit may have to be used. **Remember:** when a fusible plug clamp is applied to a 68 kg cylinder, the safety device no longer exists and it must be emptied as quickly as possible. Since there are six fusible plugs on a

tonner, sealing off one of them still leaves five operating safety devices which should be enough, under most circumstances.

b) Rupture Discs. A rupture disc is used on liquid lines on the larger installations, such as ton containers or tank cars. The disc is designed to protect the equipment and will rupture (break) when the pressure in the chlorine manifold system reaches a pre-determined value greater than normal operating pressure, but less than maximum allowable pressure. A typical installation is as follows:

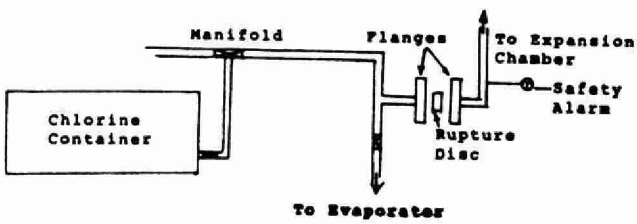


Figure 6-1 RUPTURE DISC

The rupture disc is placed between two flanges in the line to an expansion chamber. This line comes off the manifold between the chlorine container and the evaporator. This safety device should be installed in any section of liquid piping which can be isolated, either purposely or accidently, by closing valves.

Valves are carefully checked before leaving the manufacturer's plant, but occasionally a valve may be stiff to turn of difficult to shut off tight. This may be caused by a

small piece of scale or other foreign matter at the valve seat. Sometimes the valve can be freed by opening and shutting a few times (with the outlet cap in place and by tapping the body of the valve). Actually, once the cylinder is hooked up, inability to completely shut off the valve is not important and contents can be withdrawn until empty. When cylinder has been discharged (and only gas remains in it), the outlet cap with a good fibre gasket will effectively stop chlorine from escaping.

Valve Defect - "Turning Spindle"

The most troublesome type of valve defect (although fortunately not the most common) is known as a "turning spindle". Actually this is a situation where the brass threading on the valve body has been stripped by the harder Monel metal of the valve stem.

If this condition develops **after** the cylinder is hooked up to the chlorinator, the simplest and safest way to deal with it is to continue withdrawing chlorine until the cylinder is empty. However, if the cylinder has not yet been hooked up, then an emergency device is required to deal with the situation.

One manufacturer has developed emergency leak repair kits which fit on top of the valve, and by exerting pressure against the packing gland nut, pushes the valve stem into position. While this device will work in most instances, there are some situations where the use of the larger Chlorine Institute equipment with the capping device is required.

Removing Valve Outlet Cap (on Cylinder or Tonner)

ONE VERY IMPORTANT WORD OF CAUTION - when taking off the valve outlet cap (on cylinders or tonners) **DO IT VERY SLOWLY**. Actually, if there is a leak of chlorine past the valve, this will be very noticeable after the cap has been slackened only one turn. Use the ammonia bottle at this stage, and wear an air pack. Very small concentrations of chlorine can be detected by smell, and for this reason it is sometimes desirable to leave the face-mask off - just in case there are leaks. However, the air pack should be **immediately available** if required.

AS A LAST RESORT - CONTACT MANUFACTURER!

If these remedies do not solve the leaking problem, CONTACT THE MANUFACTURER. In some cases, a telephone call may provide the operator with the necessary information to correct the leak.

If this is not enough, the manufacturer's technical personnel should come, bringing the necessary emergency equipment to stop the leak.

SAFETY PROCEDURES - LEAK DETECTION

If you smell a leak:

1. Put on the SCBA.

   NOTE:

   SCBA's should be located within 4.5 m (15 feet) of the door leading to the chlorine room.

2. Turn on exhaust fan of chlorine room. Check fan discharge point and be sure personnel or equipment are not in the way. If there is a casualty, remove him immediately. Apply first aid. See Appendix D.

3. Shut off cylinders. If leak is large, or if the equipment has been leaking for some time, the room is full of gas.

NOTE:

No tests can be made on equipment for leaks until room is cleared.

DO NOT ATTEMPT A REPAIR ALONE.

4. Notify supervisor immediately. If the leak cannot be repaired, institute the emergency procedures described starting on page 6-12.

5. To test for leak AFTER room is cleared:

   a) Use bottle of concentrated ammonia near joints, piping or valves suspected. **White fumes of ammonium chloride indicate the location of a chlorine leak.**

   b) Crack open cylinder FARTHEST from chlorinator until gauge shows approx. 275 kpa or 40 psi.

   c) Shut off cylinder and test system to find leak(s). **It may be necessary to repeat above action several times to find all leakage.**

6. When location of leak is found:

   a) Mark it off clearly.

   b) Shut off gas supply and **keep supply shut off until leak is repaired.**

   c) Use proper tools for repair; do NOT handle equipment with unnecessary roughness.

A green slime, due to the gas and/or the chemical reaction, may form where a leak was repaired. A **dry** cloth should be used to wipe away the slime. The moisture from a wet cloth would combine with the slime, possibly creating another leak.

NOTE:

If this green slime has dried to a dust, do not blow it with your mouth or brush or wipe it unless the area is completely ventilated.

AVOID BREATHING THIS DUST. Even minute particles are highly dangerous.

7. If leak is not repaired before shift change:

   a) Advise next operator of what has happened.

   b) Advise him of procedures to follows.

NOTE:

If operator of first shift is alone, he should enlist the aid of the operator relieving him to check out equipment, repair leak and leave equipment in operational order before leaving.

SAFETY PROCEDURES IN EMERGENCY SITUATIONS

Suppose there is a leak from a cylinder which cannot be stopped or repaired, such as a leaking fusible plug, damaged cylinder valve, or a hole in the cylinder body. The following steps should be taken:

1. Protect yourself AT ALL TIMES during the emergency, and be sure you will not be overcome by the leaking gas. Use a SCBA when in the area of the leaking cylinder.

2. Keep the leak in the vapour phase. Cylinders and tonners should be placed so that **gas and NOT liquid** is coming off.

3. Contact your supervisor immediately and advise him of the problem.

4. If you cannot contact your supervisor, telephone the Police Department to tell them of the problem. Advise the police of the wind direction (if any) so they in turn can alert the residents who may be in the path of the gas and have the area evacuated. The police or operator should also contact the Fire Department.

5. Contact the supplier, or manufacturer, of chlorine. The suppliers operate an emergency telephone call service designed to provide assistance at any hour of the day or night. For transportation emergencies call CANUTEC 613-996-6666 (collect).

6. The chlorine room exhaust fan should NOT be turned on as this would release an excessively strong concentration of chlorine outside the plant. Under the WHMIS regulations, emergency procedures covering this situation should be referred to. **If there is a wind, the residents who may be in the path of the gas must be evacuated.**

7. If the chlorine leak occurs in a water treatment plant, it may be necessary to shut down operation and use only the water in the reservoir(s). If this reserve is inadequate and the plant cannot be shut down, then the Medical Officer of Health (MOH) should be advised so that he in turn can warn the residents to boil the water from the tap before use.

   Immediately advise the Ministry of the Environment Regional Office for the area.

8. All events which occurred during the emergency must be recorded in the Operator's Daily Log Book.

IN CASE OF CHLORINATION SYSTEM BREAKDOWN IN A WATER TREATMENT PLANT

<u>DO NOT</u> PUMP UNCHLORINATED WATER TO THE DISTRIBUTION SYSTEM. NOTIFY THE SUPERINTENDENT IMMEDIATELY. IF CHLORINATION SYSTEM CANNOT BE RESTORED TO WORKING ORDER IN TWO HOURS, NOTIFY THE MEDICAL OFFICER OF HEALTH AND THE REGIONAL OFFICE, MINISTRY OF THE ENVIRONMENT.

PERSONAL HYGIENE

For the sake of your health and the health of your family:

1. Never eat your lunch or put anything into your mouth without first washing your hands.

2. Do not smoke while working in tanks, on pumps, trucks, filters, etc. Remember, you inhale or ingest the filth that collects on the cigarette from dirty hands. Save your smoking time for lunch hours or at home.

3. Never put your hands above your collar when working on any plant equipment, if possible.

4. Don't wear your overalls or rubber boots to the dining area.

5. Always wear your rubber boots when working in tanks, around sludge, washing down, etc. Don't wear your street shoes.

6. Keep your street shoes in your locker. Remember: what your shoes pick up at the plant they will leave on the floor of your home.

7. Don't wear your coveralls or rubber boots in your car or home.

8. Have a complete change of clothing to wear when going home.

9. Always clean any equipment such as safety belts, harness, face masks, gloves, etc., after using. You or someone else may want to use it again.

10. Always wear rubber or plastic coated gloves when cleaning out pumps, handling hoses, or when working around the plant.

11. Avoid putting on gloves when your hands are dirty. Wash first.

12. Wash with plenty of water or take a shower immediately after being splashed with sludge, or any chemical. **DON'T DELAY.**

13. Don't just wash your hands before going home. Wash your face thoroughly too. There is more of your face to carry germs than there is of your hands.

14. Wear a hat when working around sludge tanks, filters, or cleaning out grit or other channels.

15. Keep your fingernails cut short and clean - they are excellent carrying places for dirt and germs.

The 30-Minute SCBA (Positive Pressure)

This unit will usually take at least 2 minutes to put on. It is a working unit as well as an emergency unit.

On the harness pressure gauge ensure the By-Pass valve is closed.

To Put On

1. Ensure that all straps are extended.

2. Place air pack on back by placing left arm through left shoulder strap, then right arm through right strap. This should be done with your body slightly leaning forward to prevent air cylinder bottle from hitting your head. This also takes some of the weight of your shoulders.

3. Buckle the chest and waist belts and adjust pack to the most comfortable position on your back by the two small straps at your shoulders in front.

4. Fully open the air cylinder valve at the base of the cylinder. The harness pressure gauge should now read the cylinders air pressure.

5. Place face mask harness to the back of your head, pull mask down over your face placing your chin in the recessed area just below the full face screen.

6. Adjust head straps starting from the bottom upwards to the top of the head; always adjust both head straps on each side of the head at the same time to guarantee centering of the mask over the face.

7. Test face mask for air tightness by placing hand over hose end and taking a deep breath. If mask draws in around face, air tightness has been obtained.

8. Follow the manufacturers recommended procedures from this point to endure trouble-free operation.

A low air pressure alarm is activated when approximately 2070 to 3450 kpa (300 to 500 psi) of air is left in cylinder. When alarm sounds, leave contaminated area immediately.

<u>To Remove Unit</u>

1. Remove procedure, shut off air cylinder valve, purge the system of air.

2. Extend all straps fully and replace air pack into holding case.

Always refill air cylinder after every time used.

FIRST AID

1. Remove patient from gas area. Patient should be kept in a warm room (about 21°C). Supply blankets under and over patient. Keep patient warm and quiet. Rest is essential.

2. Place patient on back. Place a folded coat, blanket, etc., under victim's shoulders so his head falls well back. This maintains a clear air passage to lungs of victim.

3. Call for medical aid immediately.

4. Promptly remove clothing contaminated with liquid chlorine, or chlorinated water. Keep patient warm with blankets.

5. A mixture of carbon dioxide and oxygen, with no more than 7% carbon dioxide, may be given. This mixture, already prepared and sold with the necessary apparatus, can be administered for periods of two minutes followed by two-minute rest periods for no longer than thirty minutes. Follow instructions of the gas apparatus supplier carefully. If carbon dioxide and oxygen mixture is not readily available, then oxygen alone may be used.

6. Milk may be given in mild cases as a relief from throat irritation.

7. If breathing seems to have stopped, immediately start the "Revised Sylvester" or Holgen-Neilson methods of artificial respiration. **Do not exceed 17 to 18 movements per minute.** If possible, assist respiration with an inhalator or respirator. Artificial respiration must be continued until natural breathing is restore, a doctor says to stop or rigor mortis sets in.

8. When eyes are irritated with chlorine, wash repeatedly with water and then with 1% boracic acid solution. Castor or olive oil drops may be used. In severe cases of eye contamination due to chlorine, use bubbler fountain, hose, or eye cup. Irrigate for 15 minutes. A routine of 5 minutes irrigation and 10 minutes rest should then be followed for one hour. Prompt action is absolutely essential to protect eyesight.

9. Areas of the skin which have been splashed with liquid chlorine or chlorinated water should be repeatedly washed with water. After thorough washing, any burned area should be covered with a sterile dressing and bandaged snugly unless blisters are apparent; then bandage loosely.

If facilities are available, it is generally recommended that patients be removed to hospital as soon as possible, unless recovery from chlorine exposure is prompt and the exposure mild.

SUBJECT: 3

CHLORINATION SYSTEM OPERATIONS

TOPIC: 7

START-UP AND SHUT-DOWN

OBJECTIVES:

The trainee will know and be able to demonstrate the proper procedures for starting up and shutting down the gas chlorination system.

START-UP AND SHUT-DOWN

GENERAL

Because of the hazardous nature of chlorine gas, it is essential that operators follow a fixed procedure for the start-up or shut-down of a gas chlorination system. Observing standard safety practices, together with a procedure which the operator has practised, will result in a minimum of injury-causing accidents or damage to the equipment.

Before entering the chlorine room or proceeding with the start-up or shut-down procedures, the operator should:

1. Check the condition of the SCBA's. Are they full and ready for use?

2. Check the interior of the room by looking through the observation window for indications of possible leaks or hazardous situations.

3. Ensure that he is wearing chemically resistant gloves and safety face shield.

START-UP PROCEDURE

1. Before entering the room, turn on the exhaust fan. On entering the room

   a) check exhaust fan louvers (especially in winter) to make certain that they are open.

   b) for fans mounted in the ceiling or in the upper portion of the wall, or for externally-mounted

fans, check for air suction by placing hand on the mouth of the duct. If there is no suction:

(i) check to see if FAN is running;

(ii) check ductwork for blockage.

c) check louvres on air inlet.

<u>NOTE</u>: Exhaust system (fan and motor) MUST be in operation at all times during start-up

2. Visually inspect the following and ensure that the equipment is properly hooked up:

   a) Water lines: piping, elbows, valves, tees.

   b) Chlorination lines: piping, elbows, valves, tees.

   c) Vent lines: ensure they are not plugged and are vented to the OUTSIDE.

   d) Automatic control lines (if any): purge lines for possible moisture accumulation; in vacuum or pneumatic system, purge all air from pressure differential systems.

   e) Electric lines: make sure they are plugged into sockets.

   f) New chlorine lines: ensure litharge and glycerine or teflon tape has been used on pipe joints.

3. Open valve for water supply:

   a) listen for water "whistling" through injector.

b) if no sound of water through injector, check water supply upstream.

4. Visually check the following for leaks:

   a) valves

   b) elbows

   c) piping

   d) connections

   e) if no leaks are apparent, proceed to Step 5.

5. Check to see if vacuum is obtained:

   a) Look at the vacuum gauge (if supplied) on the chlorinator; it should indicate a **vacuum** reading.

   b) If there is no vacuum (or if no gauge is supplied), disconnect vacuum line at the injector, place finger and listen for "pop" caused by vacuum (See Figures 7-1 to 7-4 for procedure).

6. Check that **ALL** valves between the chlorinator and cylinder(s) are **OPEN**. Turn handle to open as indicated on valve.

   WHY? To ensure purging of system in case of leaks.

7. Turn chlorinator feed control to a low feed position.

8. Crack open cylinder valve <u>and close again</u>.
WHY? If there is a bad leak in the system, the source of chlorine will already be isolated.

Place the wrench provided by the manufacturer on the valve stem, stand behind the cylinder valve outlet and, grasping the valve firmly with the left hand, hit the wrench a sharp blow in a counter-clockwise direction with the palm of the right hand. Do not pull or tug at the wrench as this may bend the stem, causing it to stick and, once opened, the valve may not close properly. **Do not under any circumstances use an ill-fitting manufacturer's wrench or a pipe wrench** since these wrenches will round the corners of the squared end of the valve stem. The manufacturer will gladly supply new wrenches on request. The use of large wrenches for opening stubborn valves should be avoided because, with the extra leverage obtained, there is danger of bending the valve stem or breaking it. To open a stubborn valve, follow the normal opening procedure but use a small block of wood held in the palm of the hand when striking the wrench. **If unable to open, contact the manufacturer or return cylinder.**

Immediately after the valve has been opened and the flow of chlorine adjusted, tighten the gland nut on top of the valve with the hand. Cylinders are shipped from the manufacturer with the gland nut slack so that the valve packing will retain its elastic properties until required for use. If chlorine is allowed to escape through the gland, the packing becomes hard and unserviceable.

9. Check chlorine pressure gauge. (See Figure 7-5) Approximately 275 kpa (40 psi) should be recorded.

10. Turn chlorinator feed control to **CLOSED** position and observe chlorine pressure on gauge drop to zero.

11. Check for chlorine leaks (See Figures 7-6 and 7-7): Using a plastic squeeze bottle containing concentrated ammonia, check all joints and piping on chlorine line **by squeezing bottle under or close to chlorine joints and piping, exhausting the ammonia vapour from the bottle.**

    NOTE: A cloud of white smoke will indicate chlorine leak (caused by chlorine reacting with ammonia.

12. **If any leaks are found:**

    a) shut cylinder valve immediately,

    b) turn chlorinator feed control to MAXIMUM to purge system.

    c) **leave chlorinator room and shut door** until pressure gauge reads ZERO (usually a window in the wall allows you to see this from outside) and fumes are exhausted to atmosphere.

    d) when pressure gauge reads ZERO, proceed with corrective maintenance for leak(s). (This may be tightening of joint, replacing leaky gasket, replacing valve, replacing split piece of pipe, etc.)

    NOTE: **Loosen and tighten diaphragm valves by hand only.**

Fig. 7-1 Unscrew
(by hand) fitting in
injector vacuum line.

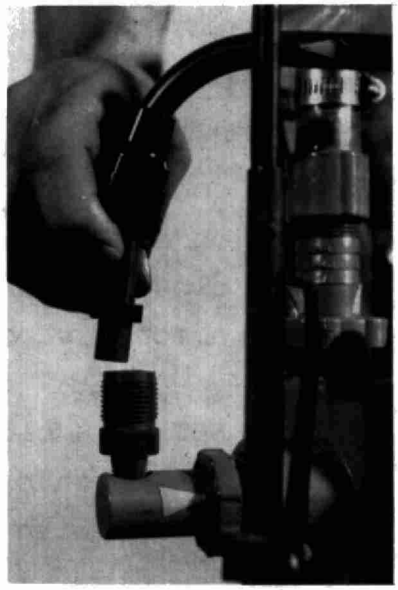


Fig. 7-2 Lift
tubing from fitting.

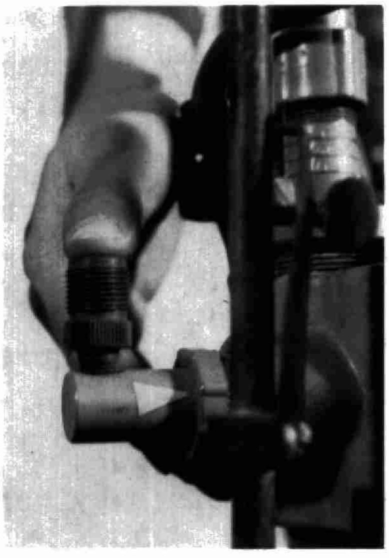


Fig. 7-3 Place
thumb over hole in
fitting, hold for
a moment.

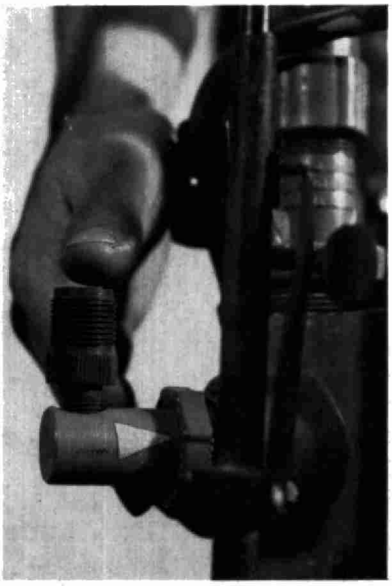
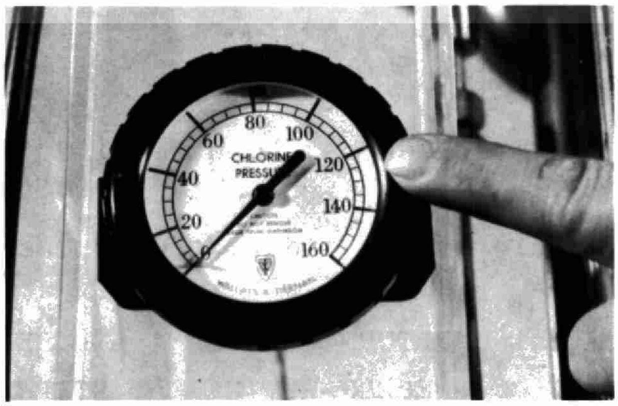
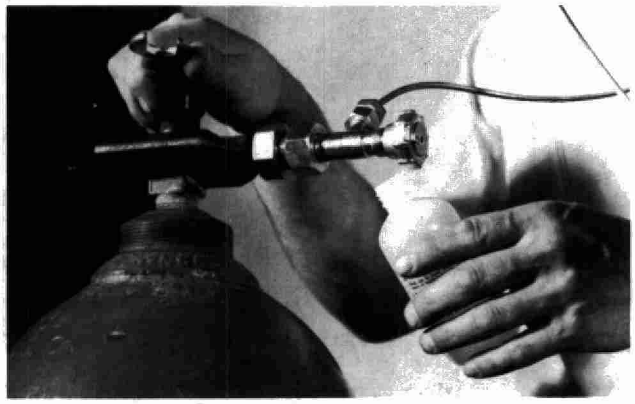


Fig. 7-4 Release
thumb and listen
for "pop" caused
by vacuum. Reconnect
tubing.

Fig. 7-5
Check chlorine
pressure gauge
for pressure.
(If machine is
so equipped)





Crack open cylinder
valve and close again.
Check for leaks at all
joints with ammonia
vapour.

Fig. 7-7
Check for leaks in
chlorinator by using
ammonia vapour.

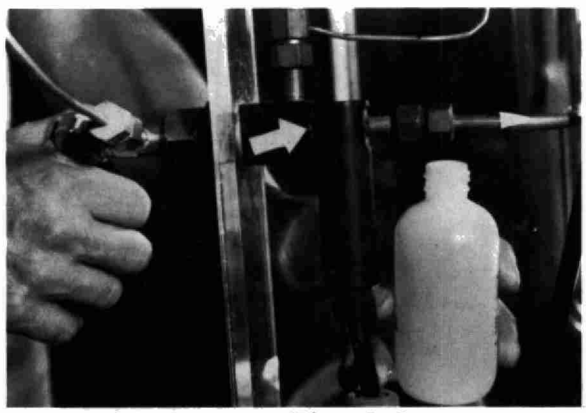


Fig. 7-8
If no leaks, open valve
then adjust feed rate.

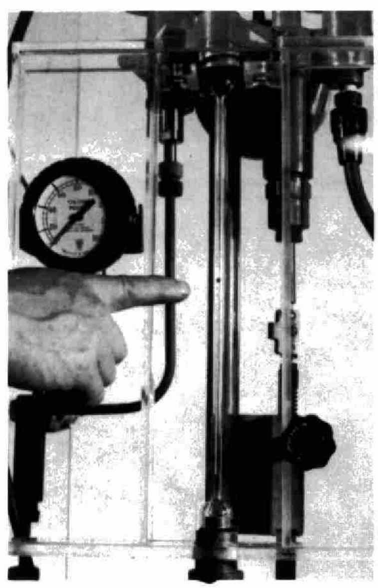
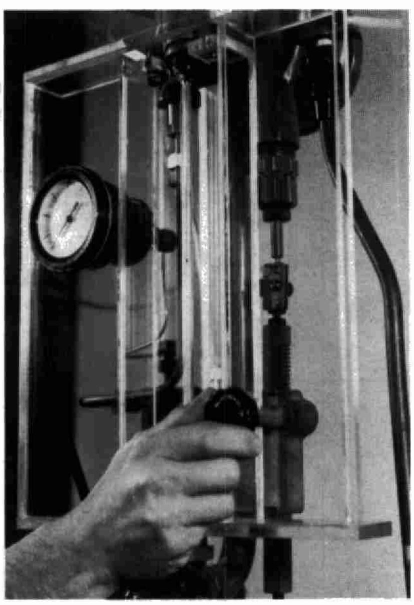


Fig. 7-9
Check ball in rotameter
for feed rate setting.



13. When leak has been repaired:

a) fully open the chlorine cylinder valve (1 turn).

b) **RETURN TO STEP 4 AND REPEAT STEPS 4 TO 11. IF NECESSARY, REPEAT STEPS 12 AND 13.**

14. **If no leaks are found:**
Adjust the chlorinator setting to the desired rate (See Figure 7-8). Check ball in rotameter for feed rate setting (See Figure 7-9).

15. If chlorination system is MANUAL, then check-out is complete. If chlorination system is AUTOMATIC, check control components for proper functioning according to the manufacturer's specifications.

TABLE 7-1

SUMMARY: START-UP SEQUENCE	
1.	Start vent fan
2.	Open water lines
3.	Check chlorinator vacuum
4.	Open cylinder and valves
5.	Check for leaks
6.	When leak-free, adjust chlorinator setting.

STARTING UP CHLORINATOR USING TWO OR MORE CYLINDERS

1. Carry out steps 1 through 7 described earlier.

2. Crack open the valve of the cylinder farthest from the until approximately 550-170 kpa (80-25 psi) of pressure is recorded on the pressure gauge of the chlorinator (if so equipped).

3. Shut of the cylinder valve and test for leaks. If there are no leaks, wait until the pressure indicated by the gauge or rotameter ball returns to zero.

4. **If the pressure gauge fails to record any pressure or rotameter ball does not move up.**

   a) Shut off cylinder valve immediately.

   b) Crack open the valve of another cylinder and close it again in one continuous motion. If there is still no pressure, the feed pipe may be plugged or other operating problems exist. **Do not attempt to repair or make adjustments to any part of the chlorine system until the chlorine gas now trapped in the feed pipes from cylinder to chlorinator has been released.**

   c) Put on a self-contained air pack with full face piece, loosen one of the feed pipe connections and allow the trapped gas to escape **slowly** from the piping. Wait until the room has been cleared of all escaping gas to make the necessary repairs or adjustments.

5. When the problem has been corrected, crack open the valve of the cylinder farthest from the chlorinator.

6. Carry out steps 9 through 13 on pages 7-5 and 7-7.

7. Crack open the valve of the second cylinder and repeat the procedure used on the first cylinder; repeat until all cylinders being used have been tested.

8. After all cylinders have been tested, fully open the valve of the cylinder to be used first. Adjust the chlorinator setting to the desired rate. Check the rotameter ball for feed rate setting.

SHUT-DOWN PROCEDURE

1. Before entering the room, turn on the exhaust fan. On entering the room:

    a) check exhaust fan louvers (especially in winter) to make certain that they are open.

    b) for fans mounted on the ceiling or in the upper portion of the wall or for externally-mounted fan, check for air suction by placing hand on the mouth of the duct.

    c) if there is no suction:

        (i) check to see if FAN is running

        (ii) check ductwork for blockage.

NOTE: **Exhaust system (fan and motor) MUST BE IN OPERATION AT ALL TIMES DURING SHUT-DOWN.**

2. Shut OFF chlorine at cylinder or manifold as required. Check pressure gauge and/or rotameter ball, making sure its reading drops to ZERO.

3. Beginning at cylinder(s):

   Shut off ALL valves as you move towards chlorinator, but

   DO NOT SHUT OFF CHLORINATOR YET.

4. Allow chlorinator to continue operating for approximately **15 minutes, without chlorine entering** it.

   WHY? To ensure complete purging of system.

5. Shut off water supply (injector) valve.

6. Shut off automatic control equipment such as electric plug positioner, variable vacuum valve, or pneumatic valves.

7. If system is shut down **longer than 10 minutes, ALL** chlorine lines must be sealed from atmosphere.

   WHY? Chlorine mixing with moisture from the air will cause corrosion of pipe.

TABLE No. 7-2

CHLORINATOR SHUT-DOWN SEQUENCE

1. Start vent fan
2. Shut off cylinder(s)
3. Check chlorine pressure
4. Shut chlorine line valves
5. Shut water valves

SUBJECT:

CHLORINATION SYSTEM OPERATION

TOPIC: 8

MAINTENANCE

OBJECTIVES:

The trainee will be able to

1. Recall the checks which should be carried out daily, weekly and annually.

2. Recall the procedure for carrying out a maintenance check of

   a) The Exhaust Fan System

   b) The Injector

   c) Rate Controller

   d) Rotameter

   e) Pressure and Vacuum Gauges

   f) Alarm System

   g) Recording Instruments.

PREVENTIVE MAINTENANCE

GENERAL

To ensure trouble-free operation to the maximum degree possible and to minimize the cost of maintenance service by the equipment suppliers, a comprehensive preventive maintenance program is essential. The following paragraphs suggest checks which should be carried out on the gas chlorination system on a daily, weekly and annual basis.

Daily Maintenance

1. Check that the SCBA's are available and serviceable.

2. Check that the exhaust fan system is operating properly.

3. Visually check

   a) Position of ball in rotameter.

   b) All pressure/vacuum gauges.

   c) Recording instruments to ensure that they are operating.

   d) The residual analyzer reading.

   e) Pump and all piping for evidence of corrosion.

4. Check temperature, pressure and water level of evaporator (if installed).

5. Check and record weigh scale reading.

Weekly Maintenance

1. Clean screens and strainers on waterlines by removing them from the lines and flushing with clear water.

2. Operate all shut-off and rate control valves to ensure proper functioning.

3. Check chlorinator vent line(s) to ensure that it (they) are not blocked.

4. Check functioning of the alarm system.

5. Check pens for recording charts.

Annual Maintenance

1. Disassemble injector. Clean components; replace gaskets, diaphragms or other parts as necessary.

2. Remove and check other components. Replace parts and packing as necessary.

3. Replace all metal chlorine gas piping leading from the cylinders to the header or chlorinator. These should be replaced after each season of use or at least once a year.

   NOTE: **DO NOT ATTEMPT TO CLEAN AND REUSE PIPING. ALL SCH 80 SEAMLESS STEEL PIPE FOR GAS OR LIQUID CHLORINE SHALL BE REPLACED AFTER 5 YEARS OF SERVICE.**

4. Touch up all metal parts with paint.

Component Maintenance

The following describes what the operator should do when carrying out the maintenance checks on the equipment listed below:

1. Exhaust Fan System

    a) Turn fan off and on to check fan operation.

    b) Turn fan off. Lock it out and tag the switch. Check fan blade for play in bearings.

    c) Turn fan on. Check fan louvers for proper operation.

    d) Check exhaust and air inlet duct work for possible blockages.

2. Injector

    a) Disassemble injector.

    b) Check nozzle (throat) for plugging by rust, or accumulation of dirt. Remove blockage.

    c) Check tailway (discharge section) of injector for abrasion (particularly true when on wells or where some fine sand may be in suspension in water).

    d) Inspect ball check - SHOULD BE CLEAN AND FREE TO MOVE.

e) Inspect diaphragm for breakage. If broken, replace.

f) Visually inspect for leaks at joints.

g) Replace gaskets where required.

h) Tighten bolts where required.

i) Check springs for corrosion or distortion.

3. Rate Controller

a) Inspect for possible linkage disconnection, or rack and pinion failure, stripped gears, broken shaft. (Operator must get in behind chlorinator to look. **Chlorinator should not be installed too close to wall.**)

b) Operate controller by hand to see if gas flow can be regulated (increased or decreased).

c) Check all seal gaskets and replace if necessary.

d) Check for foreign material on stem and seat.

e) Check automatic control by using manufacturer's procedures manual. (If chlorinator functioned satisfactorily on manual control, problem may be in the automatic control).

4. Rotameter

a) See if there is any build-up of foreign material inside rotameter and/or on the FLOAT.

b) Make sure that rotameter is properly seated at top and bottom. (See Fig. 8-1)

WHY? If rotameter is off-centre, a vacuum leak may be created, leading to faulty operation.

c) Inspect gaskets for defects (cracked or flattened). Replace if required.

5. <u>Pressure and Vacuum Gauges</u>

a) Check for leaks.

b) Open line at joint and check for plugging.

c) Open gauge by removing glass and dial face. Check gearing for wear.

<u>NOTE</u>: **Do NOT disconnect gauge from its diaphragm assembly.**

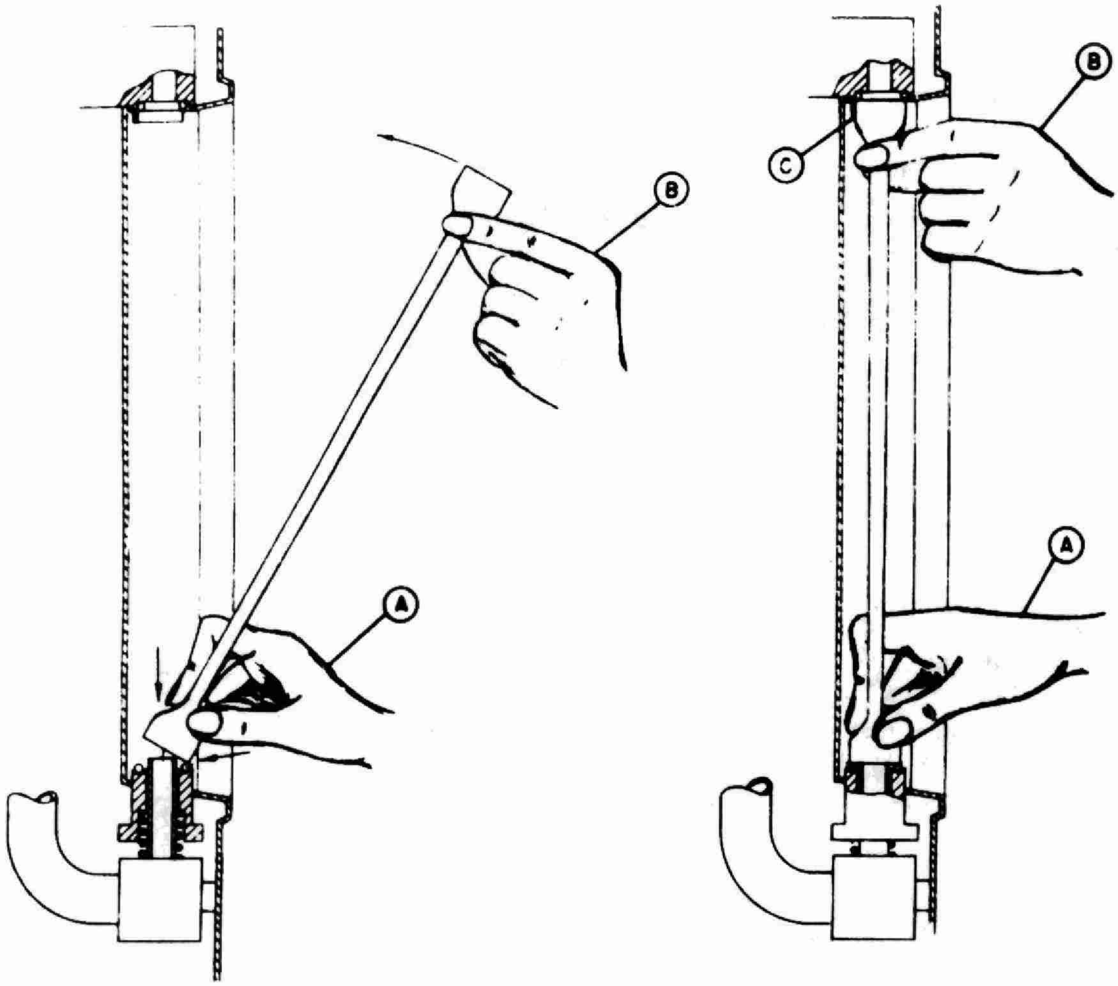
d) Check bellows for possible rupture (oil at connection to tube).

6. <u>Evaporator</u>

a) Check temperature:

(i) If it is **HIGH** (approx. 70°C), shut off power supply to heaters.

(ii) If it is **LOW** (approx. 50°C), check to see if heater is functioning, or if it is burnt out.



TO INSTALL ROTAMETER--

1. LUBRICATE BOTTOM "O" RING ONLY WITH A LIGHT FILM OF SILICONE GREASE.
2. POSITION "O" RINGS AS INDICATED. INSERT FLOAT AND STOPS IN ROTAMETER TUBE.
3. GRASP ROTAMETER BY THE TWO ENDS.
4. GUIDE LOWER END OF ROTAMETER WITH HAND "A" TO LOCATE ON "O" RING.
5. EXERT DOWNWARD FORCE WITH HAND "A" TO COMPRESS SPRING AND USE TWO FINGERS OF HAND "B" TO GUIDE TOP OF ROTAMETER INTO POSITION. ROTAMETER MUST TOUCH AT POINT "C" TO INSURE SEATING ON UPPER "O" RING.
6. RELEASE DOWNWARD FORCE ON SPRING.

TO REMOVE ROTAMETER--

1. EXERT DOWNWARD FORCE ON LOWER BELL OF ROTAMETER WITH HAND "A."
2. USE TWO FINGERS OF HAND "B" TO SWING TOP OF ROTAMETER OUTWARD.
3. LIFT ROTAMETER.

READ SCALE OPPOSITE CENTER OF BALL

Figure 8-1 ROTAMETER INSTALLATION

b) Check water level - **SHOULD BE WITHIN LIMITS SET BY MANUFACTURER:**

(i) If **LOW**, check "make-up" valve. If valve is manual, open it. If valve is automatic, it may need repair. Low level may also be caused by evaporation. Pour light film of oil over surface to prevent evaporation.

(ii) If **HIGH**, drain water to level required and be sure "make-up" valve is closed. (Leaking make-up valve causes high level).

c) Check pressure:

(i) If pressure is **HIGH**, check temperature control to see if it is functioning, because high pressure is caused by high temperature.

(ii) If pressure is **LOW**, check chlorine supply which may be low. Increase chlorine supply. Change cylinder if necessary. Check to see if thermostat is turning on heaters at LOW temperature.

(iii) Check incoming liquid pressure and be sure it is at proper level.

7. Alarm System

a) Chlorinator Malfunction.

Check functioning of system by:

(i) Turn off water to injector and wait for alarm to sound (approx. 15-20 seconds); when alarm rings, turn water on again: if alarm does NOT sound, check linkage to switch, then check diaphragm.

(ii) Turn off chlorine gas supply and wait for alarm to sound; when alarm rings, turn chlorine supply on again; if alarm does NOT sound, check linkage to switch, or positioning of switch.

NOTE: **Alarm system should be checked at least once a week.**

b) Chlorine Detector Systems using a cell assembly can be tested per manufacturer's instructions.

8. Recording Instruments: Charts and Pens (See Fig. 8-2)

a) Check if chart is bent, misaligned or jamming as it rotates.

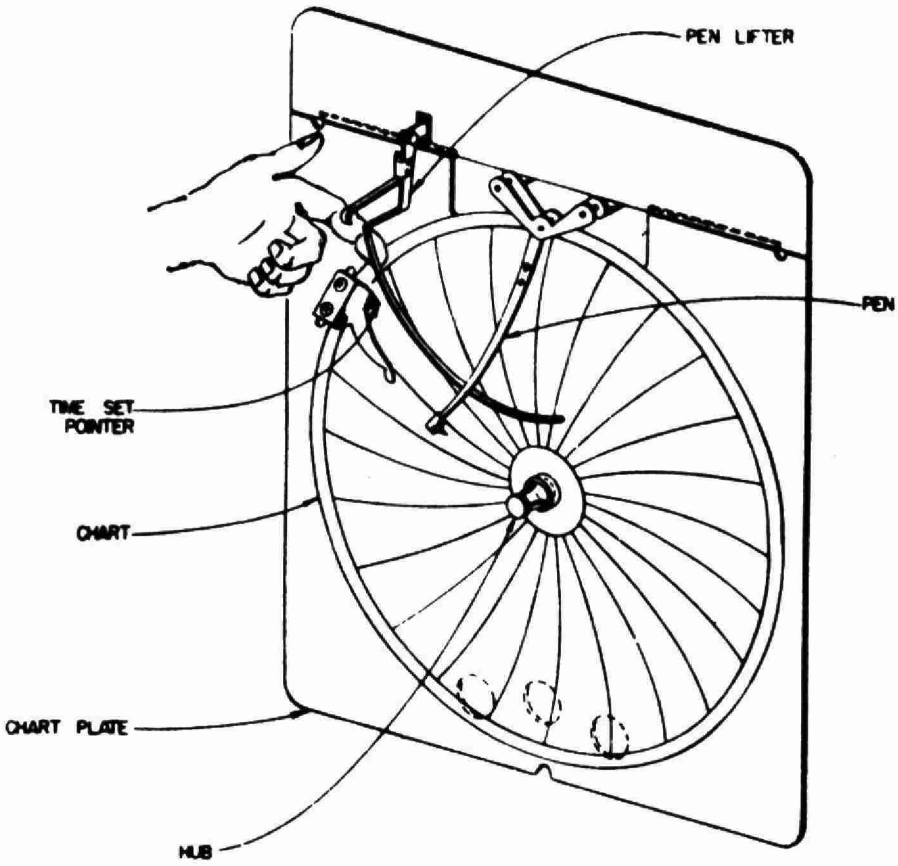
b) If pen does not print:

(i) Inspect ink-well to see if inky supply is gone.

(1) RAISE THE PEN LIFTER

(2) PULL OUT ON THE CHART HUB. IT WILL COLLAPSE INTO ITSELF, LEAVING THE CHART FREE TO COME OFF. REMOVE THE CHART.

(3) PUT ON A NEW CHART. PUSH IN ON THE CHART HUB SO THAT IT REENGAGES THE CHART.



(4) ROTATE THE CHART HUB UNTIL THE PROPER TIME ARC IS INDICATED BY THE TIME SET POINTER. (NOTE--- DAY AND NIGHT SECTIONS ON THE CHART) THE TIME SET POINTER AND THE PEN POINT REGISTER ON THE SAME TIME ARC.

Figure 8-2 CHART PLATE MAINTENANCE

(ii) Fill well as required (or replace cartridge).

(iii) Capillary tube may be plugged - run fine wire (4/1000 inch) through tube to remove foreign material.

(iv) Pen not touching paper. Check arm of pen to see if it is bent.

c) Fill through the tip with the plastic ink bottle as shown in Figure 8-3. This method of filling insures against air bubbles or other obstruction, and also primes the pen for quick starting. Put in no more ink than is estimated necessary. If there is doubt, a clean pen may be filled full the first time, but after that, the ink level should be kept as low as possible for cleanest lines and shortest drying time.
After using the plastic ink bottle, wipe the spout and replace it tightly in the sealing hole in the bottle cap.

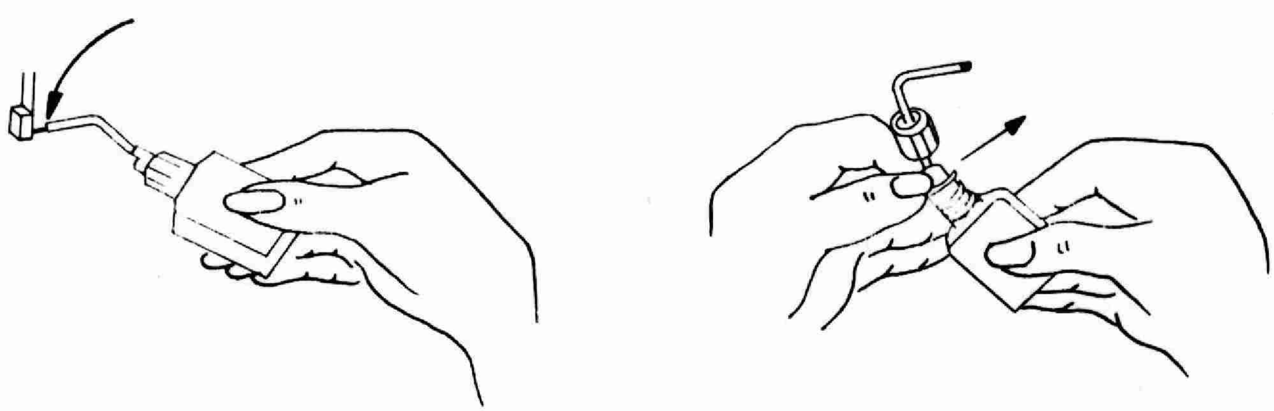


Figure 8-3 INKING A BOX PEN

d) <u>Starting a Stubborn Box Pen</u>

If trouble is encountered in getting a box pen to ink, proceed as follows:

(i) Remove the pen from the pen-arm. To do this, hold the pen-arm firmly and turn the pen in a counterclockwise direction permitting the clip on the back of the pen to be slipped off the pen-arm.

(ii) Fill the pen nearly full of ink.

(iii) Grasp the pen reservoir with the thumb on top and forefinger beneath, and squeeze. Ink should start to ooze from the pen tip.

e) <u>Maintenance of Pen</u>

If the pen becomes dirty or begins to skip, clean it as described below. Detergent cleaners may be used, but every trace should be removed or severe feathering may result. Use only recorder ink. If long service wears a pen so that the line is too wide, replace the pen.

d) <u>To Clean a Clogged Box Pen</u>

(i) Remove the box pen from its pen-arm. To do this, hold the pen-arm firmly and turn the pen in a counterclockwise direction. This permits the clip on the back of the pen to be slipped off the pen-arm. Carefully withdraw the pen from the hole in the pen-arm.

(ii) Run a wire not larger than 0.005" diameter (B&S Gauge #36 or higher) or a Cleaning Wire, Part P-26488, through the tip to push out the dried ink.

(iii) Flush out by filling through the tip with the plastic ink bottle. Force through a surplus of ink into a tissue or paper towel to make sure the tip is clean.

(iv) Replace the pen.

SUBJECT:

CHLORINATION SYSTEM OPERATIONS

TOPIC: 9

TROUBLE SHOOTING

OBJECTIVES:

The trainee will be able to recall and demonstrate the procedure for identifying and overcoming problems which arise when operating a chlorination system by knowing:

1. The likely problem area;
2. What to check and sequence;
3. Corrective measures.

CHLORINATOR TROUBLE SHOOTING

When a plant effluent is found to contain little or no chlorine residual, it is necessary to do a <u>systematic check</u> of the chlorination equipment.

The first item to check on any type of gas chlorinator would be the feed rate indicator. In the majority of instances (although not always) this will indicate in which half of the chlorinator you may locate the problem. The halves of the chlorinator you may locate the problem. The halves of the chlorinator being (a) from the chlorine cylinder through the pressure regulating valve to the feed rate indicator, (b) downstream of the feed rate indicator - between it and the injector.

Examples:

Problem #1 - A feed rate is indicated on the chlorinator.
- Low or Zero residual in the "treated"water.
- Normal pressure indicated from the chlorine cylinder.

Due to the feed rate being indicated on the ball or float of the chlorinator, you may usually assume that the system is normal at all points between the indicator and the injector.

If the chlorine is shut off at its source, the pressure may drop very slowly or not at all, but the ball will remain in a position indicating a chlorine feed. This would indicate a vacuum leak in the system between the point at which the chlorine enters the unit and the rate indicator, or in the vacuum half of the pressure-vacuum relief system.

Problem #2 - No feed rate indicated

- No residual in "treated" water.
- Normal pressure indicated from Cl_2 cylinders.

The first thing to check in the above situation is whether or not you do have a vacuum at the source. If not, check for plugging of throat or injector, water pressure failure, excessive back pressure due to partial blockage of solution lines, etc.

If a normal vacuum is found at its source, you should make progressive checks in the system following the flow pattern back to the indicator until the vacuum leak is found.

When troubleshooting a chlorinator that is on automatic control the first thing to do is put the unit on manual control. It is almost impossible to locate a problem in a chlorinator set up in the automatic position.

It is necessary, in many cases, to have the gas pressure turned on to the chlorinator when troubleshooting. This can be done with little danger of gas escaping to the atmosphere provided that NO JOINTS OR UNIONS IN THE METAL PIPING ARE DISTURBED.

Chlorine is under pressure in the metal piping only, and all plastic parts contain a vacuum. Therefore, air will be drawn into the plastic piping from atmosphere if a connection is separated, with no harm to you or the equipment.

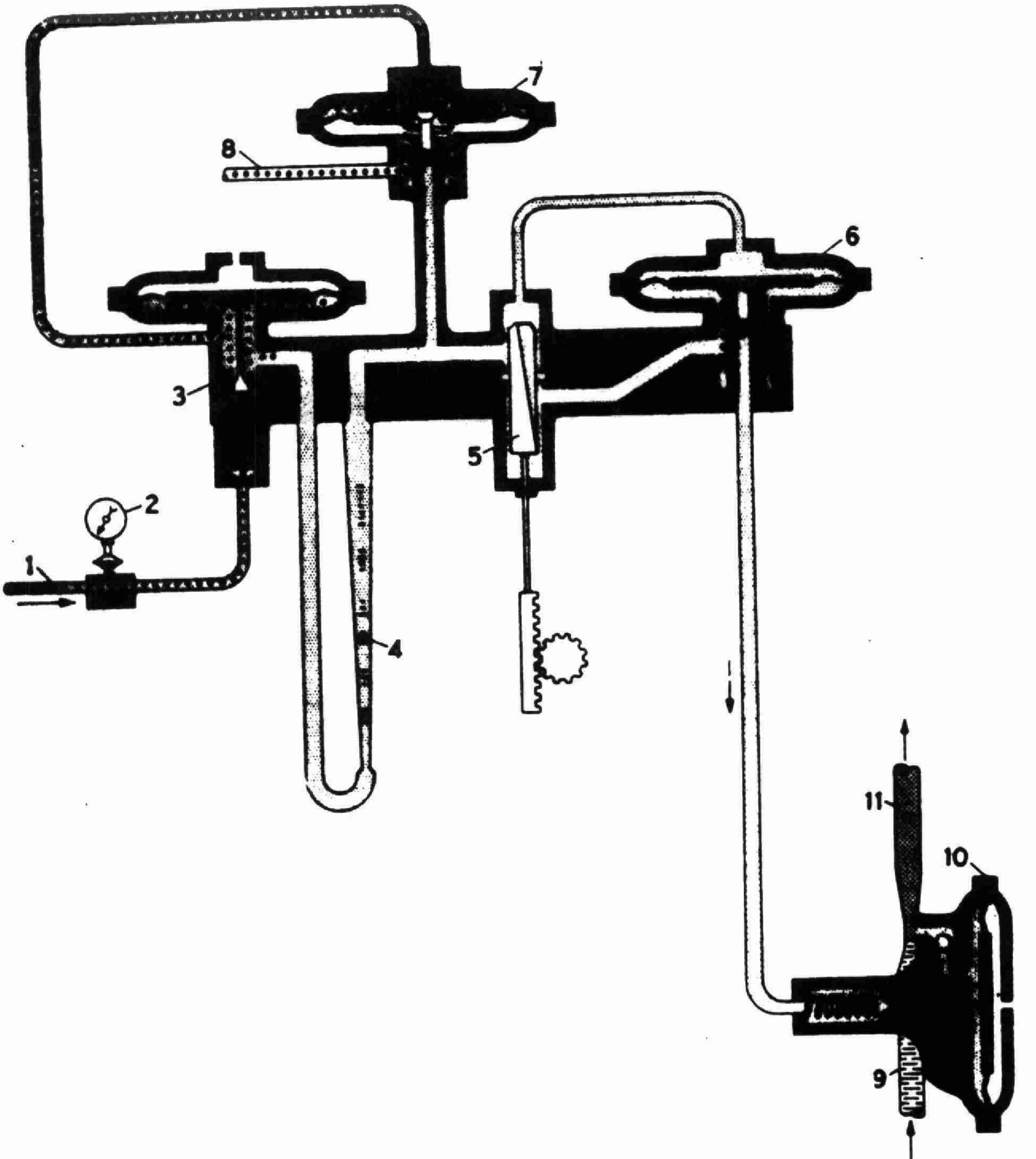
The following is a list of common problems, symptoms to look for and suggested remedies. Refer to Figure 9-1, 9-2 and 9-3 on pages 9-7, 9-8 and 9-9.

Chlorinator Symptoms	What is Probably Wrong	Auxiliary Checks	How to Remedy Symptoms
Manual chlorinator will not come up to full feed. Gas pressure adequate.	Insufficient injector vacuum.	Measure operating water pressure just upstream of injector data. Check piping for smooth flow immediately downstream of injector tailway. (No elbows, tees, reducers, etc.) Check for air leaks through diaphragm of diaphragm-type injector check valves.	Clean injector throat and tailway. Clear or replace solution discharge tubing. Provide adequate operating water pressure.
		Where injector vacuum is marginal or hydraulics are borderline, V-Notch differential is a <u>more</u> sensitive indicator of adequate operating vacuum than the injector vacuum gage. A "bobbing" rotameter float indicates marginal vacuum.	Note: A larger throat and tailway may only compound the problem as the greater flow creates more back pressure.

Chlorinator Symptoms	What is Probably Wrong	Auxiliary Checks	How to Remedy Symptoms
Manual chlorinator feeds OK at high rates, but will not control at lower rates.	CPRV not throttling sufficiently (Held open by a particle of rust, ferric chloride, etc.)	Note especially if vacuum falls at lower feeds. If it does either air or chlorine must be causing it. To find out which, turn off gas at cylinder. If rotameter float drops, it was excess gas coming in. If turning off gas does not cause float to drop, air must be leaking in. Then close off vent opening. If float drops air was leaking through the diaphragm. If closing the vent has no effect then air is leaking past a gasket.	Clean CPRV cartridge. Check CPRV diaphragm for "pin hole" leaks. Check CPRV gaskets. On "2-valve" machines, check pressure relief stem, seat and spring condition. Clean or replace parts as necessary.
	-OR- Possibly a bad diaphragm in the differential valve is causing by-passing of the V-notch control valve.	Pressurize top of differential valve with air and check for leaks in water.	Replace diaphragm on 2000# or 8000# units. Replace valve capsule on lower capacity machines.

Chlorinator Symptoms	What is Probably Wrong	Auxiliary Checks	How to Remedy Symptoms
Manual chlorinator controls OK at low feeds, but is erratic when full feed is attempted. Injector vacuum OK.	Not enough chlorine entering to satisfy demand. Dirty CPRV cartridge or partially clogged gas line.	Check gas supply pressure. See if air is entering vacuum relief port at high feeds. Check vacuum relief level.	Clean CPRV cartridge. Clean high pressure gas line. Supply adequate chlorine gas pressure (20 psi is the minimum full feed performance - except on low rate apparatus).
Chlorinator does not feed anything. Gas pressure is adequate. Injector vacuum is OK.	Tube connection from upstream of V-notch to top of differential valve is disconnected or leaking.	On automatic machines make sure V-notch plug is not remaining in closed position.	Re-connect tube line. Replace tube if cracked, kinked or defective at ends. Tighten tube nuts.

Chlorinator Symptoms	What is Probably Wrong	Auxiliary Checks	How to Remedy Symptoms
A variable vacuum control chlorinator, formerly working normally now won't go below, say, 30% feed. Signal levels OK. A variable vacuum control chlorinator reaches full feed OK but won't go below, say, 40 to 50% feed. CPRV is ok.	CPRV not throttling sufficiently for low feeds. (Held open by a particle of contaminant on seat or stem.) Signal vacuum too high because of air leak by-passing restrictor through diaphragm of control vacuum check valve.	Air-tight quality of control vacuum check valve diaphragm. Check gasket and stem in diaphragm. Check felt filter disc for restriction due to dirt or moisture accumulation. Check converter flapper and nozzle for freedom from dirt or restriction.	Clean CPRv cartridge. Re-adjust bias spring at about 20% feed after reassembly Replace diaphragm, gasket or stem as tests indicate source of leak. Clean and dry or replace filter disc.
A variable vacuum control chlorinator refuses to go to full feed. Gas pressure adequate. CPRV is clean. Injector vacuum is OK.	Signal vacuum too low because of plugged restrictor in control vacuum check valve -OR- air leaking into signal line.	Check connecting line from signal converter to chlorinator. Pressurize with air and use soap solution or submerge in water and look for bubbles. As an alternate, trap air under pressure and observe a T'ed-in vacuum gauge. Fall of pressure indicates a leak. Check joints, fittings, tube ends, retainer nuts, etc.	Remove and clean restrictor. Use solvent and a wire smaller than its 0.2 (.009 in) bore. Use teflon tape on threaded joints. Correct any vacuum leaks in signal lines. System must be "dead tight" due to very limited capacity of restrictor orifice.

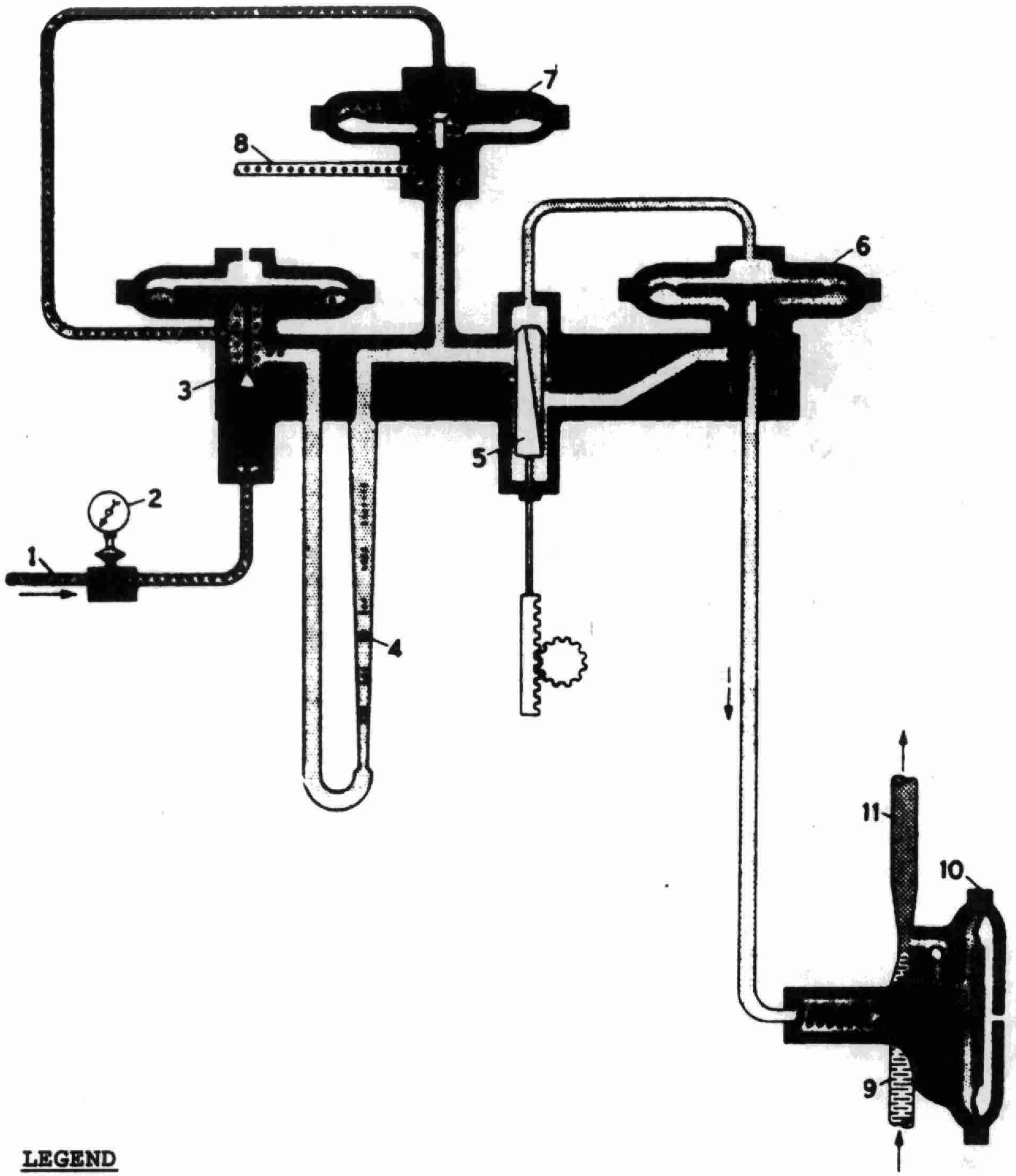


LEGEND

CHLORINE GAS......

1. **chlorine inlet pipe**
2. **pressure gage**
3. **pressure-regulating valve**
4. **feed-rate meter**
5. **orifice**
6. **vacuum-regulating valve**
7. **relief valve**
8. **safety vent**
9. **water supply pipe**
10. **chlorine inlet valve**
11. **injector**

Figure 9-1 NORMAL OPERATION

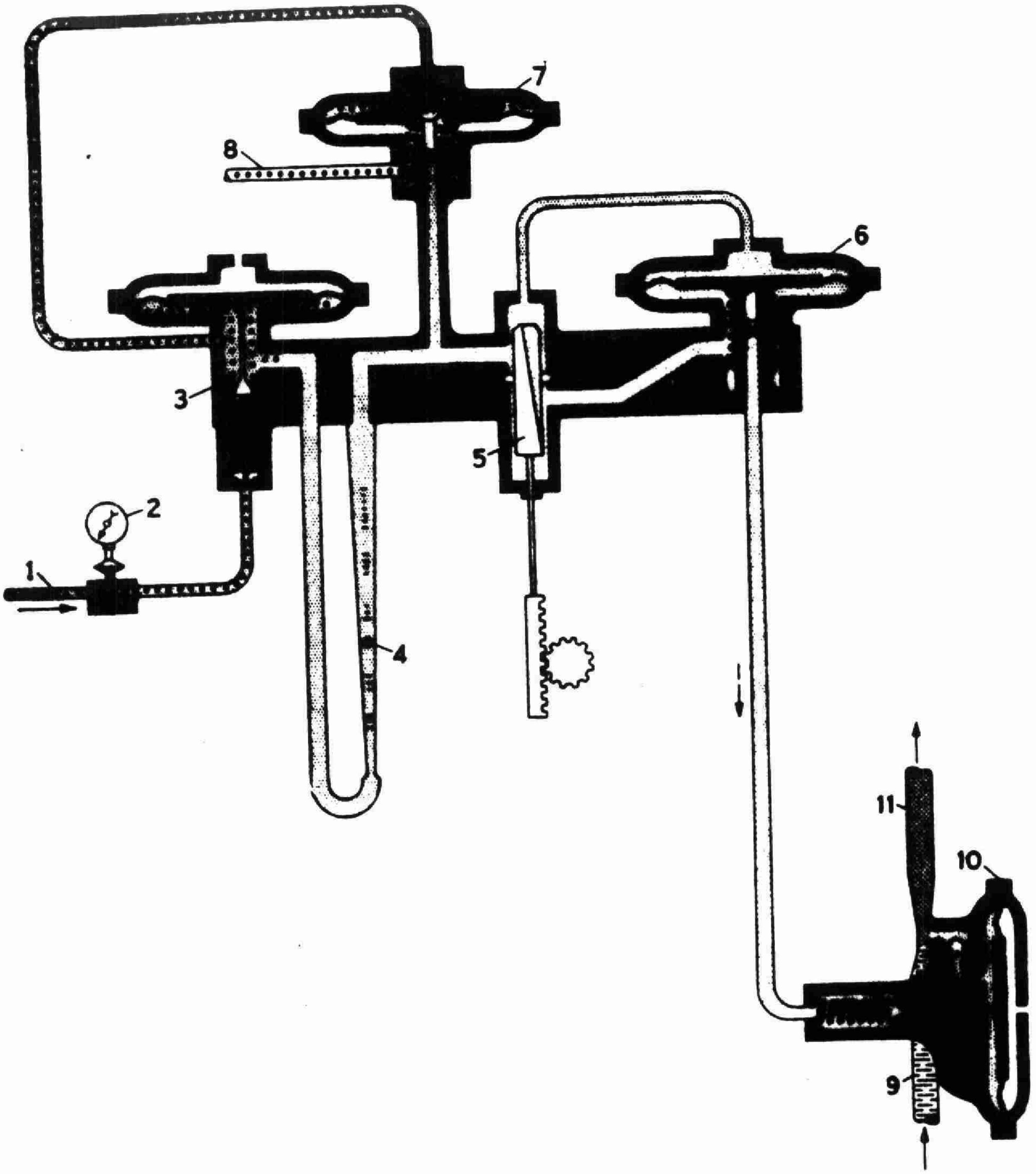


LEGEND

CHLORINE GAS......

1.	**chlorine inlet pipe**	6.	**vacuum-regulating valve**
2.	**pressure gage**	7.	**relief valve**
3.	**pressure-regulating valve**	8.	**safety vent**
4.	**feed-rate meter**	9.	**water supply pipe**
5.	**orifice**	10.	**chlorine inlet valve**
		11.	**injector**

Figure 9-2 PRESSURE RELIEF



LEGEND

CHLORINE GAS......

1.	**chlorine inlet pipe**	**6.**	**vacuum-regulating valve**
2.	**pressure gage**	**7.**	**relief valve**
3.	**pressure-regulating valve**	**8.**	**safety vent**
4.	**feed-rate meter**	**9.**	**water supply pipe**
5.	**orifice**	**10.**	**chlorine inlet valve**
		11.	**injector**

Figure 9-3 VACUUM RELIEF

SUBJECT:

CHLORINE TESTING PROCEDURES

TOPIC: 10

DPD METHOD
SPECTOPHOTOMETER METHOD

OBJECTIVES:

The trainee will be able to

Demonstrate and carry out the procedures for determining the chlorine residual using the DPD method with the Nesslerizer and Comparator.

CHLORINE TESTING PROCEDURES

DPD METHOD

Principle of the Method

Research in chlorine chemistry has resulted in the development of a very simple procedure for the determination of its free and total residual. With the new method differentiation between the combined forms of chlorine is also possible using the DPD indicator. The test has a high precision and accuracy and when properly used it can be an excellent aid in the control of chlorine residual at a water treatment plant.

A good feature of the Lovibond Comparator method lies in its use of compressed tablets which are convenient to handle, more stable than the DPD solution, and is a procedure of exceptional simplicity. In a recent investigation by the Water Research Association this method was judged the BEST COLORIMETRIC METHOD for the measurement of chlorine and chloramines in water.

Equipment and Reagents Required

1. DPD tablets for Comparator and Nesslerizer

    a) Nos. 1 & 3 together for total chlorine residual.

    b) No. 1 for free chlorine.

2. Comparator with Standard Lovibond Discs

    a) 3/40A disc covers the range 0.1 to 1.0 mg/l chlorine.

b) 3/40B disc covers the range 0.2 to 4.0 mg/l chlorine.

These discs require 13.5 mm. cells or test tubes. A dulling screen must be used.

3. Nesslerizer with Disc

NDP covers the range 0.05 to 0.5 mg/l. This disc must be used with a dulling screen and 50 ml tubes.

Procedure

1. Comparator

a) Determining Total Chlorine Residual

i) Place a 13.5 mm cell or test tube containing sample only in the lefthand compartment, behind the colour standards of the disc.

ii) Rinse a similar cell with the sample, and fill the cell or tube up to the mark with it.

iii) Into this cell or tube drop one No. 1 and one No. 3 tablet (or one No. 4 tablet, which is No. 1 and No. 3 combined).

iv) Allow tablets (or tablet) to disintegrate until effervescence ceases.

v) **Mix rapidly** to dissolve the remains of the tablet.

vi) Place the cell in the righthand compartment of the Comparator.

vii) **After 2 minutes**, match the cells by holding the Comparator facing a good source of diffused north daylight and **resolve this disc until the correct standard is found. NEVER LOOK INTO THE SUN.**

viii) The figure shown in the indicator window represents mg/l of **total chlorine residual** present in the sample.

b) Determining of Free Chlorine Residual

i) Prepare tubes as outlined above for total chlorine residual, one "blank" tube and one with just a few drops of sample.

ii) To the tube with sample, add one No. 1 tablet only.

iii) After disintegration, add water up to mark, and

iv) Mix as before and match at once. This gives **free chlorine residual.**

Note: It is permissible to determine TOTAL CHLORINE on the same sample by continuing as follows: add one No. 3 tablet, mix and stand for 2 minutes. The colour then read **off represents total chlorine residual.**

c) <u>Determining Combined Chlorine Residual</u>

Total Chlorine Residual - Free Chlorine Residual = Combined Chlorine Residual Value.

2. <u>Nesslerizer</u>

Follow exactly the same procedure for the Comparator, with the following exceptions:

a) Use 50 ml instead of 10 ml.

b) Use special Nesslerizer DPD tablets.

<u>Note</u>: **It must be emphasized that the readings obtained by means of the B.D.H. Lovibond Nesslerizer and disc are only accurate provided that Nesslerizer glass is used which conforms to the specification employed when the discs are calibrated, namely, that the 50 ml calibration mark shall fall at a height of 113 ± 3 mm, measured internally.**

3. <u>False Colour due to Interferences</u>

a) The only interfering substance likely to be present in water is oxidized manganese from potassium permanganate in those water plants that use if for taste and odour control.

b) Test the unchlorinated water for colour development and use as a Blank.

c) **All glassware used must be very thoroughly rinsed after making a test, since only a trace of potassium iodide will cause chloramine colour to develop. Handling the tablets should be avoided. By shaking one tablet into the bottle top, it is a simple matter to use the top for conveying the tablet to the Comparator cell or Nessler tube.**

SPECTOPHOTOMETER METHOD

Principle of Operation

The spectophotometer as shown in Figure 15-1 is a single-beam analytical instrument that measures concentrations of particular substances in water colorimetrically. These substances are reacted chemically, causing the colour to vary in intensity in proportion to that concentration. A variable interference light filter is used to select the wavelength of light seen by the photocell.

This instrument gives a high degree of accuracy for the measurement of free and total chlorine residuals.

Procedure

1. Spectophotometer Setup

a) The standardizing solution (usually the original water sample) is placed in the cell holder and the lid closed. Only clean, dry sample cells should be placed in the instrument and with either clear side toward the light source.

b) Ensure that the chlorine meter scale has been inserted and the Wavelength Dial adjusted to 530 mm.

c) To zero the instrument, the light switch is held in the ZERO CHECK position while the ZERO ADJUST control is used to obtain a zero transmittance reading (needle aligned with the mark at the extreme left of the arc).

d) The instrument is standardized by setting the light switch to ON and using the LIGHT CONTROL to obtain a meter reading of 0 mg/l (extreme right mark of the scale arc).
The instrument does not need to be zeroed each time a test is performed, but frequent checks of the zero adjustment are recommended.

2. <u>Sample Analysis</u>

<u>Determining Free Chlorine Residual</u>

a) Fill cell with water to be tested to the 25 ml mark.

b) Add the contents of one DPD Free chlorine Reagent Powder Pillow and swirl to mix. A pink - red colour will develop if chlorine is present. To allow time for proper colour development, wait at least 3 minutes, but not more than 6 minutes.

c) Place sample in cell holder and read the mg/l chlorine.

Note: **If the sample temporarily turns yellow when adding the DPD reagent or reads above the 2 mg/l mark the chlorine concentration is too high for the meter scale and a sample dilution is necessary.**

Determining Total Chlorine Residual

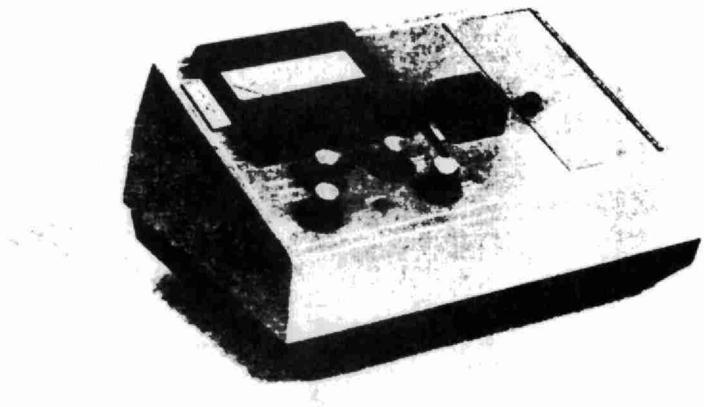
a) Using the same sample add the contents of one DPD total chlorine Reagent Powder Pillow. Swirl to mix. Wait at lease 3 minutes.

b) Place sample in cell holder and read to mg/l chlorine.

Determining Combined Chlorine Residual

Total Chlorine Residual - Free Chlorine Residual = Combined Chlorine Residual Value.

Figure 10-1 SPECTOPHOTOMETERS



"HACH" SPECTOPHOTOMETER - LAB MODEL

"HACH" SPECTOPHOTOMETER - PORTABLE MODEL

SUBJECT:

CHLORINE TESTING PROCEDURE

TOPIC: 11

AMPEROMETRIC TITRATION

OBJECTIVES:

The trainee will be able to:

1. Explain the principle of operation of the Amperometric Titrator.

2. Demonstrate chlorine testing using the Amperometric Titrator.

AMPEROMETRIC TITRATION METHOD

GENERAL

The most accurate methods of measuring free and combined chlorine residuals is through oxidation-reduction titration procedures. Such methods require the use of internal indicators or electrometric devices employing a suitable electrode system to show when reactions are completed. Amperometric titrators employing rotating platinum electrodes have been developed for such purposes. See Figure 11-1, page 11-11.

Phenylarsene oxide is the reducing agent normally used as the titrating agent. It reacts with free chlorine residuals at pH 6.5 to 7.5 in a quantitative manner.

By conducting a two-stage titration, with the pH adjusted at about 7 and then at about 4, it is possible to measure separately free chlorine residuals and combined chlorine residuals.

Titrator - Principle of Operation

Titration is a method used to determine the concentration of a substance in a solution. This is accomplished by adding the smallest amount of a reagent (of known concentration) required to cause a neutralizing effect, in reaction with a known volume of the test solution. A graduated vessel (or burette) is used to add the reagent to the known volume of test solution until the chemical reaction between the tow is completed. The point of completion is indicated by either (a) adding an indicator dye and watching for a change in its odour <u>or</u> (b) stopping at a predetermined end point on a pH meter or microammeter.

A direct current potential is impressed across two nodal metal electrodes immersed in a measuring cell containing the sample of the solution to be tested. Any flow of current between the electrodes is directly proportional to the quantity of halogen (such as chlorine, bromine, or iodine) in the sample. The presence of a current is indicated on a microammeter at the top of the instrument.

A reagent (also called a titrant) is added in small doses to the sample, and reacts chemically with the chlorine present in the solution, thereby neutralizing a portion of the chlorine. As more titrant is added, more chlorine is "removed", causing the current flowing between the electrodes to diminish as indicated by the microammeter pointer moving down the scale. Finally, sufficient titrant is added to react with all the chlorine, and no further decrease in current is possible. This is called the end point.

The amount of chlorine residual present in the test solution is determined by noting the number of millilitres of titrant used to attain the end point. Then:

mg/l of chlorine = mls of titrant that have been used

Procedure

1. **Filling the Burette**
   Make sure the titrant (phenylarsene oxide solution) fills to the zero mark.

2. **Titration of Free Chlorine Residual**
   a) Fill the solution jar with 200 ml of sample.
   b) Add 1 ml pH 7 buffer solution.
   c) Fill the microburette with the titrant (phenylarsene oxide solution) to the zero mark.

d) Titrate by adding phenylarsene oxide solution and observe current changes on the microammeter. As long as addition of phenylarsene oxide produces a definite decrease in current, free chlorine residual is present.

e) The end point is just passed when a very small increment of phenylarsene oxide no longer causes a decrease in current.

f) The burette is then read and the last increment of titrating solution is subtracted from the reading to give a value representing the free chlorine residual.

3. **Titration of Total Chlorine Residual**

a) To the sample remaining from the free chlorine titration add 1 ml potassium iodide solution and then 1 ml pH 4 buffer solution IN THAT ORDER.

b) Titrate with phenylarsene oxide solution to an end point, just as above for the free chlorine residual. It is most convenient NOT to refill the burette but simply to continue the titration.

c) After concluding the titration and having found the end point, subtraction of the last increment again gives the amount of titrating solution actually used in reaction with the chlorine.

d) If the titration was continued without refilling the burette, this figure represents the total chlorine residual. Subtracting the free chlorine residual from the total gives the combined chlorine residual, or

Total Chlorine Residual - Free Chlorine Residual
= Combined Chlorine Residual

NOTE: It is essential to wash the apparatus and sample cell thoroughly to remove iodide ion and acetate buffer after this determination, in order to avoid inaccuracies if the titrator is subsequently used for free available chlorine determination.

e) If desired, the determination of the total chlorine residual and the free chlorine residual may be made on separate samples. If only the value for total chlorine residual is required, it is permissible to treat the sample immediately with 1 ml potassium iodide solution followed by 1 ml pH 4 buffer solution. The titration is carried out with phenylarsene oxide solution as described on page 11-3 (2(c)).

Monochloramine and Dischloramine Differentiations

It is often desirable to differentiate between the monochloramine and dischloramine portion of the combined chlorine residual in a sample solution. This differentiation is accomplished in the following manner:

1. Perform the procedure outlined in Procedure for the Titration of Free Chlorine Residual. Note the reading in ppm (free chlorine).

2. Add 4 to 5 drops of potassium iodide, 5% solution to the sample jar. If monochloramine is present, the ammeter pointer will deflect to the right.

3. Titrate to the "end point"; note the reading in ppm.

4. Add 1 dropper of pH 4 buffer solution and add 1 dropper of potassium iodide, 5% solution to the sample jar. If dichloramine is present, the ammeter pointer will again deflect to the right.

5. Titrate to the "end point"; note the reading in ppm.

The difference between the readings obtained in step 1 ("free" chlorine) and step 3 preceding, represents the monochloramine component.

The difference between the readings obtained in step 3 and step 5 represents the dischloramine component.

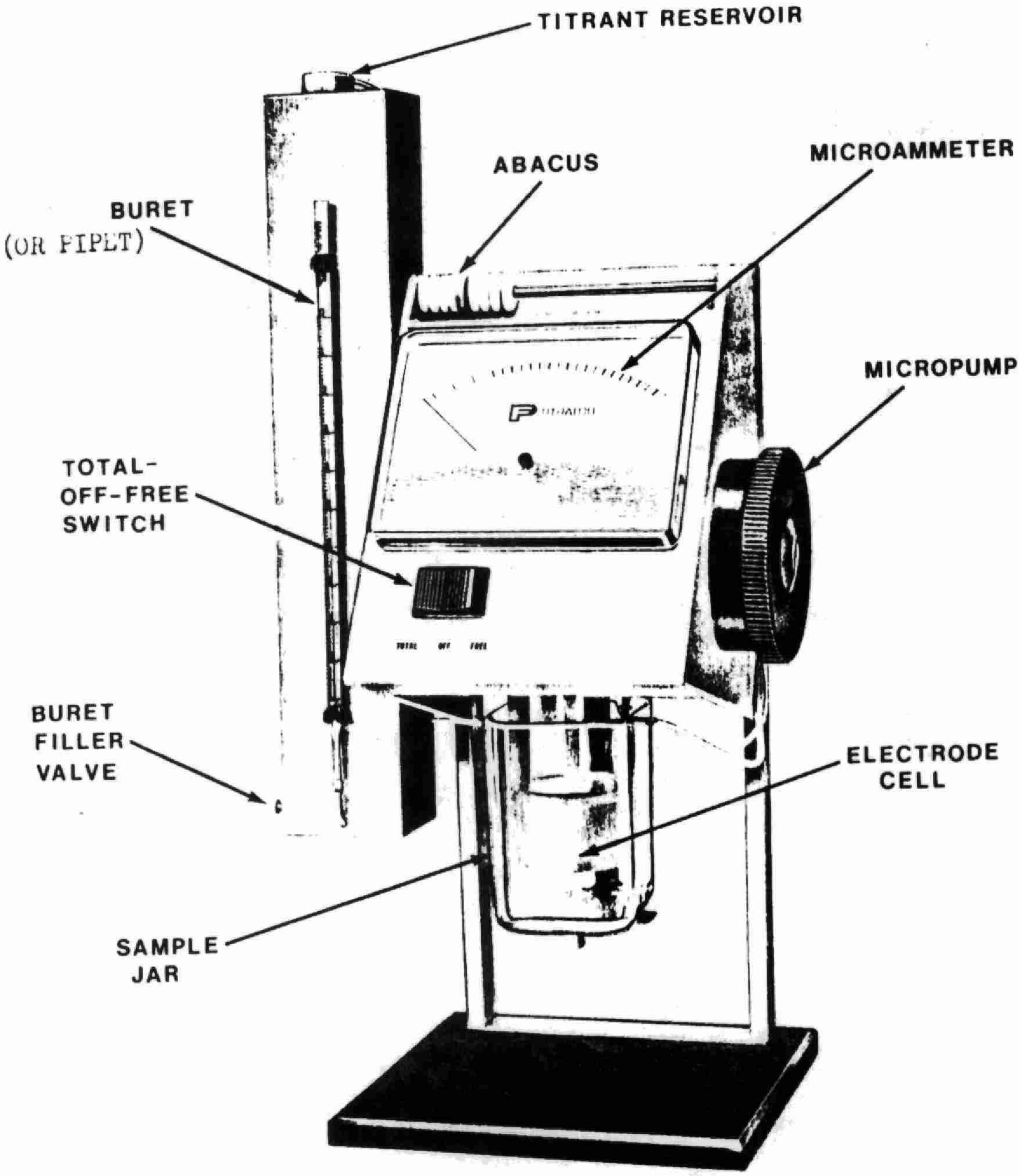


Fig. 11-1 Amperometric Titrator
(Courtesy Fischer & Porter)

GLOSSARY OF TERMS

BREAKPOINT (CHLORINATION)

Point at which near complete oxidation of chloramines and other chlorine combination is reached. Any residual beyond breakpoint is mostly free available chlorine.

CHLORAMINES

Compounds of organic or inorganic nitrogen and chlorine. The reaction of free available chlorine with ammonia and many organic amines to form chloramines, principally mono-chloramine and dischloramine.

CHLORINATION

The application of a chlorine solution to a water supply or wastewater stream for the principal purpose of reducing population of harmful disease causing bacteria to an acceptable level.

Refer to Bulletin 65-W-4 (see appendix) for details.

CHLORINE DEMAND

The difference between the amount of chlorine added to water or wastewater and the amount of chlorine residual remaining at the end of a specified contact period.

CHLORINE RESIDUAL

Chlorine remaining in water or wastewater at the end of a specified contact period as combined or free chlorine. The chlorine residual for any given water varies with the amount of chlorine applied, time of contact, temperature, pH and the amount of chemical and organic contaminants in the water.

COMBINED CHLORINE RESIDUAL

The chlorine in water in chemical combination with primarily ammonia or other nitrogenous compounds. Combined chlorine residual is measured by taking the difference between Total and Free chlorine residuals.

DECHLORINATION

A deliberate treatment of water to remove excess residual chlorine. Normally done prior to sending water out into system.

DISINFECTION

The reduction of harmful bacterial populations as defined by the Ontario Ministry of the Environment drinking objectives.

FREE CHLORINE RESIDUAL

Amount of chlorine available as hypochlorous acid or hypochlorite ion that is not combined with ammonia or other organic amines. It is much more powerful than combined chlorine residual.

FREE RESIDUAL CHLORINATION

The addition of chlorine to water until the requirements of ammonia and nitrogenous compounds are met plus a slight excess.

NOTE: This excess will then be in the form of hypochlorous acid which will attack and destroy the chlorinated ammonia and protein substances formed by the initial does of chlorine. All the resulting residual will consist of 90% or better hypochlorous acid.
Free residual chlorination is particularly useful where large numbers of bacteria must be killed in a chemically contained water. It has been clearly demonstrated that it will also inactivate the viruses. This system of chlorination is also noted for colour removal and is effective for the reduction of taste and odours in a raw water supply.

GAS CHLORINATION

Chlorine gas mixed with water to form solution to treat water or wastewater.

HYPOCHLORINATION

The addition of hyposchlorites, such as sodium or calcium hypochlorite, to the water or wastewater to be treated. It is added in solution form usually by means of a diaphragm positive displacement pump. Used where chlorine requirement is small or where gas cannot be fed (safety, lack of water pressure).

MARGINAL CHLORINATION

The addition of chlorine to water or wastewater to produce a total chlorine residual in the range of 0.2 to 0.5 mg/l.

OXIDATION - IN TERMS OF TASTE AND ODOUR PROBLEMS

A chemical breakdown of complex organic compounds used in connection with the destruction of tastes and odours in water.

PARTS PER MILLION

Parts per million (ppm) and milligram per litre (mg/l) are commonly used terms for expressing concentration in water and wastewater operations. It is a measure of a very small amount of a substance in a very large amount of water. Ppm and mg/l are the same and can be used interchangeably, or

1 mg/l = 1 ppm

PRECHLORINATION

The application of chlorine to a water supply at the beginning of the treatment process.

POSTCHLORINATION

The addition of chlorine to water after turbidity removal.

STERILIZATION

Total destruction of bacterial populations. We never sterilize in the water or wastewater industry.

SUPERCHLORINATION

The application of chlorine to water to provide free residual chlorination. The dosages are greatly in excess of those normally required for normal disinfection purposes but are effective in destroying objectionable taste and odour producing substances.

TOTAL CHLORINE RESIDUAL

Summation of free chlorine residual and combined chlorine residual.

TERMINAL STREAM: GEORGIAN Ba

DATE	ISSUED TO